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SUPPLY OF AVAILABLE SOIL PHOSPHATES AND THEIR ACCUMULATION WHEN PHOSPHORUS FERTILIZERS ARE APPLIED

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THE importance of mineral fertilizers in the agriculture of the USSR is increasing every year. For a number of years cotton, sugar beets and other technical crops have been abundantly supplied with mineral fertilizers. Nitrogen is applied under cotton in the form of mineral fertilizer in an amount equal to that which is removed with the cotton crop, while more than twice as much phosphorus is applied under cotton as is removed and more than three times as much phosphorus is applied with fertilizers under sugar beets as is removed with the crop. Further, the number of sowings intensively fertilized with phosphorus will increase. For this reason, the question of the availability of phosphates remaining in the soil after removal of the crop is acquiring great national economic significance.

The requirement of plants is about three times less for phosphorus than for nitrogen. With small crops (of the order of about 10 centners of grain, 100 centners of potatoes or beets, or 10 centners of raw cotton), 10 to 15 kilograms per hectare of P_2O_5 and 30 to 45 kilograms per hectare of nitrogen are removed. The utilization coefficient of the nitrogen of mineral fertilizers is 70 to 80%, that of phosphorus only 10 to 20%. The low utilization coefficient of phosphates is sometimes related to the harvest of only the first crop, noting the possible residual effects of phopsphates (11). Consequently, if the increase in the crop is provided by the nutrients from mineral fertilizers, the ratio of N to P_2O_5 in the composition of the fertilizers (without considering the residual effects of the fertilizers) should be about 1:1.5, while the ratio of N to P_2O_5 in the nutrients removed with the crop is about 1:0.3.

Intensifying the nitrogen nutrition of plants may take place not only at the expense of the fertilizers applied, but also at the expense of other sources, such as the biological nitrogen of legumes and of green manure. For this reason, if it is true that there is such a low utilization coefficient of the phosphorus from phosphorus fertilizers, then, as the crop grows and as a large part of it is being created by the mineral fertilizers applied, the proportion of phosphorus in the fertilizers should not decrease. But the statistics of the world production and use of fertilizers testify otherwise. As long ago as 1944 it could be noted that neither the crises in industry nor in agriculture in the capitalistic countries could change the undeviating growth of the proportion of mineral nitrogen in fertilizer production (14).

The ratio $N:P_2O_5$ in the production of mineral fertilizers in 1913 was 100:420; in 1938 it was 100:145; and in 1954 it was 100:122. In some countries in which mineral fertilizers had been used intensively for a long time, the amount of nitrogen in the fertilizers became even greater than the amount of phosphorus (Holland, Japan) or equal to it, as is taking place in West Germany (17). In the United States where the production and use of fertilizers has been intensively developed, the $N:P_2O_5$ ratio in fertilizers, which had been 100:224 in 1938, became 100:126 in 1954. Thus, although nitrogen is more expensive than phosphorus, the use of nitrogen is increasing considerably more rapidly. But the use of expensive nitrogen fertilizers cannot be profitable without satisfying the phosphorus requirement.

In countries in which the crops have been more than doubled following the systematic use of mineral fertilizers (France, Italy), an average of less than 30 kilograms per hectare of P_2O_5 is applied to crops, while in countries which have more than tripled their yields (England, Germany, Denmark, Holland) 35 to 50 kilograms per hectare of P_2O_5 is applied. In the United States at present about 20 kilograms of P_2O_5 per hectare of crop is applied and this has led to an increase in yields of about one and a half times, although the intensive use of phosphates there began quite recently. If the low utilization coefficient of phosphates were really true, then with good yields they would have had to apply two to three times the amount of phosphates they are actually applying now.

Countries which have systematically used phopshorus fertilizers for many years have evidently created in the soils supplies of non-utilized phosphates which now make possible a greater use of nitrogen fertilizers than of phosphorus fertilizers. In Germany in 1923, soils which had normally been fertilized with phosphates before failed in 72% of the cases to give an increase in yield when phosphorus fertilizers continued to be applied (21). The optimal N:P:K ratio in the composition of fertilizers cannot be constant: it depends not only on the peculiarities of the soils and plants, but also on the quantities in which fertilizer is applied, the level at which crops absorb them, and the amount previously applied (12, 13). For example, if we suppose that a full supply of phosphorus for the first year of cotton on sierozem requires the application of nitrogen and phosphorus at 100 kilograms each, that is, a N:P ratio of 1:1, then, when cotton is cropped for the second year, along with 100 kilograms of nitrogen, it will be enough to apply about 50 kilograms of phosphorus since more than half of the phosphorus has remained unutilized in the soil. The correct N:P ratio, which had been 1:1 for the first year, became 2:1 for the second year; but cotton is grown in one place not for just one year but for four or more, so that an N:P ratio of 1:1 is not appropriate for calculating the average cotton phosphorus requirement.

Before the availability of labelled fertilizers, the intake by the plant of phosphorus from the fertilizer was determined by the difference in amount of phosphorus removed by fertilized and unfertilized plants. The basis of this "differential" method of determining the utilization coefficient of fertilizer phosphorus was the supposition that soil phosphates are equally utilized on fertilized and unfertilized tracts. This supposition proved to be false. The quantity of phosphorus removed from fertilizers, as determined by the use of labelled fertilizers, proved to be different in a number of cases from the removed quantity as determined by the "differential" method.

In soils there are large supplies of phosphorus compounds of different degrees of solubility and availability; these supplies have been calculated to amount to 10 to 35 metric tons of P_2O_5 in the top one-meter layer of one hectare. The phosphorus content of the plow layer of clay loams and clays is 100 to 250 milligrams per 100 grams of soil. The utilization by plants of 10 to 30 kilograms of P_2O_5 per hectare is not perceptibly reflected on the total supply of phosphates in the soil. The prolonged and unchanging cultivation of grains at the Rothamstead and Poltava experiment stations shows that every year for many years the soils can supply the necessary quantity of phosphates for producing grain crops.

Plants which absorb soluble phosphates upset the equilibrium between the phosphates of the solid phase of the soil and those of the soil solution, with the result that new portions of phosphates go into solution. When water-soluble phosphates are applied to the soil, they dissolve in the soil solution and are adsorbed from it by the soil, since the equilibrium between the solid phase of the soil and the solution is thus upset. As a result, in fertilized soils there is an increase in the amount of mobile, freshly-precipitated compounds adsorbed by the soil which are the main source of phosphates which dissolve when plants absorb phosphorus. Thus, conditions are created in fertilized soil making it possible to use less of the soil phosphates that dissolve with difficulty than in unfertilized soil. Because the differential method showed only slight utilization of phosphorus from fertilizers, it was inferred that fertilizer phosphates reverted in the soil becoming fixed in a form which is unavailable to plants. Knowing only the actual utilization coefficient of fertilizer phosphates one could still calculate to what extent they remained in the soil and what residual effects they might exert.

These discussions concerning the utilization of phosphates from fertilized soil naturally do not apply to the local use of phosphates in small quantities when it is possible to intensify the utilization of soil phosphates as a result of faster growth rate of the plants (3).

In 1950 the Scientific Institute for Fertilizers and Insectofungicides and the V. V. Dokuchayev Soil Institute initiated experiments with the radioactive isotope of phosphorus by the method of selective absorption of phosphates (15). Some results of the experiments carried out by this method have been published (3, 6, 16). In setting up experiments by the method of selective absorption of phosphates, the two forms to be compared are introduced into the same container. Determination of how much of the phosphorus of each of the forms of phosphates is absorbed by the plants is based on the fact that one of the forms is labelled, the other unlabelled. If the experiment is carried out with plants grown in soils, then in one container the first form is labelled and the second form unlabelled, while on the other hand, in another container the first form is unlabelled and the second form is labelled.

We used the method of selective absorption for estimating the content of available phosphorus in the soil. As nutrients the plants receive soil phosphates and phosphorus from applied fertilizer. Knowing the total quantity of phosphorus in the soil and in the fertilizer, one can calculate their comparative availability. But the results of such experiments give data which can be compared only with difficulty. When water-soluble fertilizers are used, the phosphates react with the soil and are materially changed. For example, in soil with a high content of mobile iron and aluminum compounds the formation of freshly precipitated phosphates may be expected from sesquioxides; in soil with a high content of calcium carbonate, the formation of dicalcium phosphate may be expected. Consequently the results of the experiments do not give us information concerning the comparative availability to plants of the applied water-soluble phosphate and of the soil phosphates, but rather information concerning the soil phosphates and those forms of them which have just been created from the fertilizer; and these latter forms depend on the chemical composition of the soil, since the amount of biological fixation of phosphates is negligible. The conversion of soluble phosphates into other forms may vary with different quantities of applied phosphates as a result of the existence in the soil of factors of fixation which vary in capacity and intensity. The application of a phosphorus fertilizer changes the composition and properties of phosphates already in the soil, so that with different quantities, forms, dates, and methods of application of labelled fertilizers we will get different estimates of the soil content of available phosphates in the experiments.

A special method was suggested for obtaining comparable data on the characteristics of the availability of soil phosphates. This method was described at the International Conference on the Peaceful Uses of Atomic Energy at Geneva in 1955 (16). In experiments set up by this method the characterization of available soil phosphate is carried out by determining the stipulated total supply of available phosphates in the soil (x) and its utilization coefficient (k). The experimental design uses the application of a measured amount of labelled phosphate containing only a negligible amount of total phosphorus (the carrier). In this case the stipulated store of available phosphates in the soil is determined by the formula

$$x = \frac{P \cdot 100}{k},$$

in which P is the amount of phosphorus (more precisely, of P^{31}) taken into the plant, while k is the percentage of P^{32} in the intake by the plant. By applying an extremely small quantity of labelled phosphate we exert almost no effect on the phosphorus nutrition of the plant or on the content, composition, or availability of the soil phosphates. This quantity of the radioactive phosphorus isotope applied to the soil is, as it were, a label for the more mobile soil phosphates which take part in the transfer of phosphates from the soil solution into the solid phase of the soil and vice versa.

If all of the available phosphates in the soil were to have the same utilization coefficient as the phosphates marked with our label, then the value of x obtained would be equal to the soil content of the form of phosphates which was determined. But under the conditions existing in the soil, the nutrition of the plants is provided by various phosphates—and not in proportion to their relative content in the soil; some phosphates may be abundant but less soluble, while others may be scarce but more soluble. For this reason the value of x gives us the total nutritive value of all the soil phosphates conventionally expressed as the number of milligrams of P_2O_5 which are equivalent in their availability to the most mobile of our labelled soil phosphates. Consequently, the value of x may not be considered except as a function of k, that is, the utilization coefficient of P^{32} or of its labelled phosphates which is the same thing. This is the methodological difference between the estimation of available phosphates carried out by our method and that carried out according to the formula of Larsen (22) and of Fried and Dean (23), who suggested calculating the supply of available phosphates in the soil on the basis of the percentage of labelled phosphorus taking part in the total content of phosphorus in the plants and the quantity of phosphorus applied as labelled fertilizer. In this case the determination of the utilization coefficient of P^{32} (k in our formula) is not carried out. Now, one determination of the amount of the supply is in many cases of theoretical and practical significance, as shown by

TABLE 1

Supply of available phosphates in the soils and the percentage utilization of P^{32}
(According to data of K. F. Gladkovaya)

Soil	Percentage utilization of P^{32}	Available phophates as mg. of P_2O_5 per 100 g. soil
Peat-medium podzolic clay loam	13.6	14.6
Same, but limed	21.9	16.1
Peat-medium podzolic sandy loam	7.3	15.1
Thick chernozem	23.3	20.8
Typical sierozem	24.4	8.5
Krasnozem	0.63	59.5

the valuable work of Larsen, Fried and Dean, and other investigators. However, considering the supply of available phosphates as equivalent to the water-soluble phosphates of fertilizer without calculating the value of k makes it impossible to reveal many peculiarities of phosphate conditions not only of different types of soils, but also in soils which had previously been fertilized differently (Table 1).

Phosphate conditions in thick chernozems differ from those in peat-podzolic soils not so much in the supplies of available phosphorus as in the degree of their mobility, as characterized by the values of k, the utilization coefficient of labelled phosphates. The phosphate conditions in a typical sierozem (on a nonfertilized plot) are distinguished by a small supply of available phosphates, and by a high coefficient of their utilization. Finally, unfertilized krasnozem has a large supply of "available" phosphates, but the degree of their availability is extremely low. Liming podzolic soil greatly increased its utilization coefficient but left almost unchanged the supply of available phosphates. Knowledge of one value of the supply of available phosphates fails by a wide margin to give an idea of the phosphorus nutrition on various soils. On limed podzolic soils, on chernozems and on sierozems, as a result of the high mobility of the available phosphates of these soils it is easy, through the application of fertilizer, to create a large supply of phosphates which will assure the phosphorus nutrition of the plants. The use of superphosphate in large quantities under cotton on irrigated sierozems brought about phosphate saturation of the soil—such a concentration of phosphates in the soil that a new application by broadcasting phosphorus fertilizers no longer gave a positive effect. The presence in sierozem soils of a high content of available phosphates under cotton, and the need for differential application of phosphorus fertilizers depending on the soil content of these phosphates, are now the subject of special investigations (20, 7). In 1937 while investigating the intensively fertilized fields of the Pakhta-Aral State Farm, A. A. Lazarev (9) noted a great increase in the content of available phosphates there. The abundant accumulation of available phosphates in sierozem when phosphorus fertilizers were applied was also observed in experiments at the Ak-Kavak Experiment Station (8, 19).

TABLE 2

Supply of available phosphates in the soils in milligrams of P_2O_5 per 100 grams of soil and the percentage utilization of P^{32}. Soils used were from tracts of a perennial experiment by the Dolgoprudnaya Agricultural Chemistry Experiment Station with forms of phosphorus fertilizers. (According to data of A. A. Maleinaya)

Tracts of the field experiment	% of P^{32} utilized	Supply of available phosphorus	Supply of available phosphorus provided by fertilizer
NK (background)	15.0	11.2	—
Superphosphate	19.1	21.1	9.9
Half of quantity of superphosphate	23.6	14.7	3.5
Phosphate rock	22.1	16.0	4.8
Double quantity of phosphate rock	20.4	21.4	10.2

Acid, unlimed peat-podzolic soils, and especially krasnozems contain phosphates which are available to plants but which have a low degree of mobility. But in krasnozems, too, phosphorus saturation may be reached. This will be of great economic significance, as shown in papers from the All-Union Institute of Tea and Subtropical Crops. Single applications of large quantities of superphosphate or systematic applications annually of normal amounts of superphosphate caused phosphorus saturation of the soils of tea plantations for more than 20 years (18, 5, 1). Moreover, the systematic application of phosphorus fertilizers on peat-podzolic soils leads to their saturation with phosphorus for a number of years (10).

Table 2 shows data for some tracts used in perennial field experiments with forms of phosphorus at the Dolgoprudnaya Agricultural

Chemical Experiment Station. The application of phosphorus fertilizers raised the utilization coefficient of phosphates and led to such an accumulation of available phosphates that their content in the soil was doubled.

The application of half-quantities of superphosphate and unit quantities of powdered raw phosphate rock led to a one and a half times increase in the store of available phosphates. The smaller accumulation of available phosphates when powdered raw phosphate rock is applied is evidently explained by the failure of phosphate rock to be converted to the available forms.

Determination of the soil supply of available phosphates by the experimental application of P^{32} (with a negligible quantity of carrier) is based on the proposition that the P^{32} is distributed among different forms of the mobile phosphates of the soil in proportion to their participation in the process of transferring phosphorus from the solid phase into the soil solution and vice versa. If this proposition is true, then applied phosphates must be present in the soil to a considerable extent as "exchangeable" phosphates, that is, phosphates which can be displaced by the use of an isotopic phosphate extract. The method of determining exchangeable phosphorus in the soil is a good deal short of being perfected. In T. D. Koritskaya's experiment (6) (Table 3), the labelled phosphates (100 milligrams of P_2O_5 per kilogram of soil) were then displaced by Zerenson's phosphate buffer solution of pH 7.0 and a soil-to-solution ratio of 1:25. The quantity of exchangeable phosphates proved to be almost identical in different soils. But an experiment set up with wheat showed that the degree of availability of exchangeable phosphates is extremely varied. Consequently, application of dissolved phosphates creates in soils approximately uniform supplies of available phosphates, but with different degrees of mobility.

TABLE 3

Content of exchangeable labelled phosphorus in the soil recoverable by phosphate extracts, and the intake of labelled phosphorus in plants. Quantities shown are milligrams of P_2O_5 per kilogram of soil. (Experiment by T. D. Koritskaya)

Type of soil	Transfer of phosphorus into phosphate extract	Labelled phosphorus removed with crop
Thick chernozem	56	20.1
Typical sierozem	64	19.2
Peat-medium podzolic clay loam	53	12.0
Peat-podzolic sandy loam	53	3.8
Krasnozem	47	1.3

Our proposition about the presence in peat-podzolic soils and krasnozems of large supplies of available phosphates (with a low degree of mobility) seems at first glance to contradict the data from chemical analyses determining available phosphates in soils by the use of different extracts (A. T. Kirsanova, E. Truog, F. V. Chirikova and others). At the time when extraction of available phosphates is taking place, secondary processes of phosphate precipitations which have already gone into solution are occurring. As a result of this the phosphorus content of the solution does not give a correct representation of the quantity of phosphates which can be dissolved in a given reagent (2). If, when the soil extraction is being carried out, there is added an absolutely negligible quantity of labelled phosphate which does not affect the result of the P_2O_5 analysis of the extract, it is possible by the use of the well-known equation

$$\frac{P^{32}(\text{soil})}{P^{32}(\text{solution})} = \frac{P^{31}(\text{soil})}{P^{31}(\text{solution})},$$

to determine the total content of available phosphates in the solution and in the soil.

The results of K. F. Gladkova's experiments (4) are given in Table 4. The total content of available phosphates in soil and solution proved to be far greater than in the solution alone. Many available phosphates are subjected to secondary precipitation during the analysis of soils which fix phosphates strongly. For example, in a krasnozem ten times as much phosphate was dissolved in weak acids as remained in the solution.

TABLE 4

Soil phosphate content soluble in various solvents in milligrams of P_2O_5 per 100 grams. (According to data of K. F. Gladkovaya)

Solvent	Thick chernozem		Peat-medium-podzolic clay loam		Krasnozem	
	Solution	Solution + soil	Solution	Solution + soil	Solution	Solution + soil
0.2 n HCl	17.8	32.8	10.8	22.3	1.1	9.8
0.02 n H_2SO_4	12.9	15.3	8.3	10.7	3.3	6.4
0.05 n CH_3COOH	10.6	19.4	4.7	18.6	0.3	12.0
1% citric acid	20.8	33.9	30.7	51.5	6.9	69.0

Consequently, our concepts of the soil supplies of available phosphates and of the abundance with which available phosphates are accumulated in the soil were considerably understated.

The systematic annual application of phosphorus fertilizers under such crops as cotton or tea in the so-called normal quantities (usually two to three times as much phosphorus as the crop removes) leads to phosphorus saturation of the soil. For valuable crops sown on a limited area, phosphorus saturation cannot be considered to be a negative phenomenon, but the technique of using phosphorus fertilizers on these soils should be different: it should only ensure intensive nutrition of the young plants and the preservation of the state of phosphorus saturation of the soil. The detection of areas of phosphorus saturation of the soil is one of the routine duties of soil scientists and agronomists. New rules should be worked out for the use of fertilizers, especially for areas of soil which are already saturated with phosphates. A survey should be made of the distribution of phosphorus fertilizers among different regions and different crops of a field rotation. This will make it possible to free hundreds of thousands of tons of superphosphates to fertilize grain and fodder crops while still fully assuring the further growth of technical crops. The development of theoretical research in the field of phosphorus nutrition of plants is making it possible now to carry out on a scientific basis substantial changes in the use of phosphorus fertilizers and, through more correct use of them, to achieve greater additional production of grain and feed.

Conclusions

1. Setting up vegetative experiments with the application of P^{32} (with a negligible quantity of carrier) makes it possible to characterize the supply of available phosphates in the soils and the degree of their mobility.

2. Depending on the type of soils available phosphates are not uniformly mobile, and for this reason the supply of phosphorus to the plants in different soils must vary depending on the amount of available phosphates supplied.

3. When applied to the soil water-soluble phosphates are generally converted into exchangeable available phosphates with a degree of mobility which corresponds to a given type of soil.

4. Determination of available mobile phosphates by the use of slightly acid and other extracts of the soil causes secondary precipitation at the time of extraction and thus gives a considerably underestimated idea of the solubility of soil phosphates. This was established by analyses in which the radioactive label was added to the extracts.

5. In regions where phosphorus fertilizers are used intensively, there is vigorous accumulation of available phosphates in soil requiring reconsideration of the methods of applying phosphates.

6. Previously held ideas about the extremely low utilization coefficient of the phosphorus in fertilizers, and about the quick reversion in the soil of superphosphate with its conversion to forms which are not available to plants, are not realistic.

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USE OF GYPSUM ON SOLONIZED CHESTNUT SOILS OF THE SOUTHERN UKRAINE TO INCREASE FERTILITY

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Solonization of the chestnut soils of the southern Ukraine is manifested primarily in the differentiation of the soil profile and in the presence of a compacted solonetz (illuvial) horizon which, although it has a negligible content of absorbed sodium, is nevertheless distinguished by physical properties unfavorable for agriculture (4). Some loss of structure and decreased water permeability, as well as a tendency to crust formation which are unfavorable to growth, combine to cause a decrease in crop production. The necessary density of grass stands is not formed on solonetz soils.

In general the yield of a grain crop depends on the number of ear-bearing stems. The relation between the number of ear-bearing stems and other indexes of the makeup of a winter wheat crop is shown in Table 1.

The considerable proportion of moisture which is inaccessible to plants in the solonetz horizon and the decreased mobility of the moisture aggravate the water deficit in dry years, thus further depressing plants cultivated on solonetz soils.

Among the methods of improving solonetz soils, the most widely used is application of gypsum. In the first experiments with chemical improvement of solonized chestnut soils in the southern Ukraine by A. M. Mozheiko (3), it was noted that under dry-farming conditions the use of gypsum was followed for the first several years by a decrease in productivity; he explained this by the effect of Na_2SO_4, present as an exchange product. For this reason under dry-farming conditions Mozheiko considered the prospects of using gypsum on solonized chestnut soils as questionable. It is probably on this incidental conclusion that he based his recommendations for methods and rates of applying gypsum. Up to the present time most persons have considered it as established and indeed incorporated into agricultural law, that gypsum should be applied only on spots of solonetz if their area did not exceed 50% of the total area and only if solonization was strongly manifested. The rate of application of gypsum recommended was 3 to 5 metric tons per hectare. Such a recommendation for the "differential" application of gypsum cannot be complied with in practice considering that the spots of solonetz are very unequally distributed and that their shape, area, and degree of solonization are variable (Fig. 1). On tilled fields the area of solonetz spots rarely exceeds 20 to 30%. The soil in general consists of solonized chestnut soil, and the primary problem is increasing its fertility.

I. G. Moiseyev (5) noted a positive effect of gypsum on the solonized chestnut soils of the northern Caucasus. This consisted of an increase in permeability to water, improvement in the composition of absorbed cations, and an increase in the yield. Use of gypsum as a method of increasing the productivity of the dark solonized chestnut soils of the Ukraine was referred to by Ya. Ya. Motuzov (6). According to his data, the winter wheat crop on the experimental field at the Kherson Agricultural Institute increased between two and three centners per hectare from 1937 to 1939 when four metric tons per hectare of gypsum was applied. The physical properties of the soil also improved.

It has been established by the work of the Ukrainian Scientific Research Institute of Irrigated Agriculture and of other experimental institutions that the best rate of application of gypsum on the southern Ukrainian solonetzes is four metric tons per hectare. In experiments at the Skadov Experimental Station we used this rate of application and distributed the quantity evenly over the entire area with a fertilizer spreader. The field experiments were carried out on areas consisting in one case of 0.9 ha. and in another of 0.5 ha. The use of areas of this size made it certain that they would reflect the characteristic spottiness of the soil cover in each modification of the experiment, thus making it possible to record the changes in the physicochemical properties of the soil, to carry out observations on the growth and development of the crops, and to calculate the yields on the different soil conditions. Before setting up the experiments we carried out a large-scale soil

TABLE 1

Characteristics of stands and yields of winter wheat on the soils of solonetz complexes

Soil	Number of ear-bearing stems per M^2	Av. No. of grains per ear	1000-grain weight, grams	Yields, centners per ha.
Dark-chestnut, slightly solonized	420	24.0	29.8	22.3
Chestnut, strongly solonized	326	25.0	30.5	15.8
Deep columnar solonetz	253	20.0	27.1	9.7
Columnar solonetz	110	17.0	27.0	4.5

survey of the areas with compilation of a 1:500 soil map. It was done in accordance with the instructions on scientific methodology for the execution of experimental work on the improvement of solonized soils by agricultural and biological methods as worked out by the V. V. Dokuchayev Soil Institute of the Academy of Sciences of the USSR. Observations on the change in physicochemical properties of the soil were carried out separately on especially secured areas for solonized chestnut soil and for solonetz. Areas were set aside for the study of the physical properties of the soil and for taking analytical samples. Mixed samples from ten borings were taken for chemical analysis. Determinations were carried out in duplicate. Soil moisture was determined by averaging three parallel tests. Permeability determinations were carried out in duplicate by field measurement using V. M. Krychnikov's apparatus.

The grain crop was calculated separately for each soil variation by setting up 20 check areas of one square meter for each soil variation within the limits of each modification of the experiment. The total yield from the area was determined by the weight of the grain as collected by the combine harvester. The fractional calculated yield of raw cotton was done on the basis of test sites in five places in the area of modification. The area of each test site on solonized chestnut soil was 50 to 60 square meters.

On the experimental area the water table is at a depth of 5.6 to 6.0 meters, almost at the level of the Black Sea. Its salt content consists of sulfates and chlorides at a concentration of 1.3 to 2.4 grams per liter. The moderately and slightly solonized chestnut soils have a humus-eluvial horizon 22 to 25 cm. thick. Total humus in the plow layer (0 to 22 cm.) is 1.6%; in the layer below this (22 to 30 cm.) it is 1.4%.

Application of gypsum on the experimental tract was carried out in 1953. Investigations carried out in the next three years showed that as early as the first year (1954) gypsum had im-

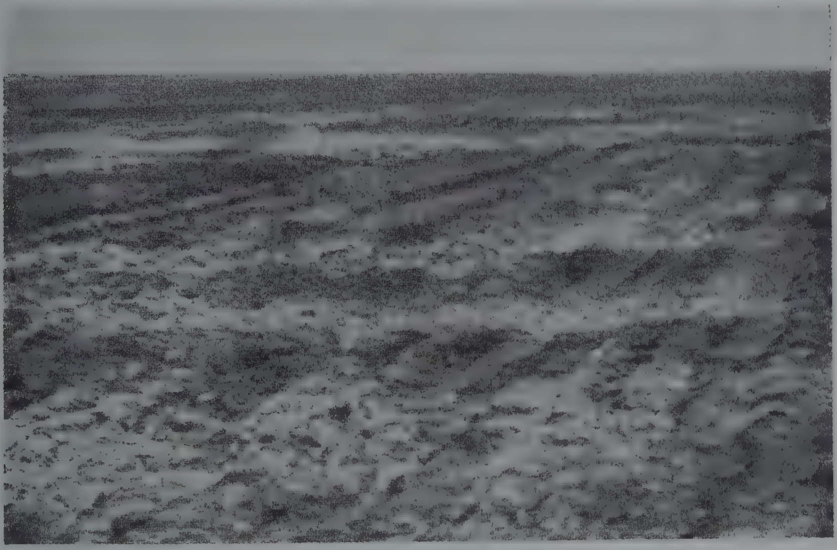

FIG. 1.—Surface of a fall-plowed plot in spring: soil complex of the south of the Ukraine. Photograph by the author.

proved the agricultural physical properties of the solonized chestnut soils, had made possible an increase in the amount of water absorbed, and had increased the depth to which the soil was wetted by water. The effect of gypsum was increased in the years following this.

TABLE 2

Quantity of absorbed water in millimeters after a three-hour run

Depth of tillage, cm.	1954		1955		1956	
	Without gypsum	With gypsum	Without gypsum	With gypsum	Without gypsum	With gypsum
30	316.0	320.5	284.5	320.5	222.5	267.5
45	370.0	377.0	315.0	347.5	239.0	291.0

Note: Deep tillage was carried out in 1953 at 45 centimeters. In the following years usual plowing was carried out in this treatment of the experiment.

TABLE 3

Effect of gypsum on the dispersion of solonized chestnut soil (Content of particles less than 1 micron diameter in percent)

Treatment	Year observed	Depth in centimeters				
		0–10	10–20	20–30	30–40	40–50
Without gypsum	1956	0.95	1.11	1.78	2.20	2.12
First year after gypsum	1954	0.98	1.03	1.77	2.11	2.19
Second year after gypsum	1955	0.84	0.92	1.50	2.27	2.15
Third year after gypsum	1956	0.79	0.87	1.52	2.19	2.11

TABLE 4

Effect of gypsum on the proportion of adsorbed cations in solonized chestnut soil plowed 25 centimeters deep

Year of gypsum effect	Depth of sample, cm.	Absorbed cations, me./100 g. soil				Adsorbed cations as % of total		
		Ca	Mg	Na	Total	Ca	Mg	Na
Without gypsum	0–10	17.6	1.3	0.7	19.6	89.8	6.6	3.6
	10–20	16.9	2.3	0.8	20.0	84.5	11.5	4.0
	20–30	18.1	1.8	0.8	20.7	87.4	8.7	3.9
	30–40	17.3	1.9	0.9	20.1	86.1	9.4	4.5
	40–50	16.8	1.7	1.2	19.7	85.3	8.6	6.1
First year after gypsum (1954)	0–10	18.3	0.8	0.5	19.6	93.3	4.1	2.6
	10–20	18.7	1.7	0.5	20.9	89.5	8.1	2.4
	20–30	18.3	2.0	0.7	21.0	87.2	9.5	3.3
	30–40	17.2	1.8	0.9	19.9	86.4	9.1	4.5
	40–50	17.2	1.8	1.0	20.0	86.0	9.0	5.0
Second year after gypsum (1955)	0–10	18.6	1.2	0.7	20.5	90.7	5.9	3.4
	10–20	18.2	1.0	0.7	19.9	91.5	5.0	3.5
	20–30	18.2	1.1	0.8	20.1	90.5	5.5	4.0
	30–40	17.5	1.7	0.8	20.0	87.5	8.5	4.0
	40–50	16.7	1.7	0.9	19.3	86.5	8.8	4.7
Third year after gypsum (1956)	0–10	19.1	1.1	0.5	20.7	92.3	5.3	2.4
	10–20	18.7	1.3	0.6	20.6	90.8	6.3	2.9
	20–30	18.3	1.2	0.6	20.1	91.0	6.0	3.0
	30–40	17.6	1.8	0.9	20.3	86.7	8.9	4.4
	40–50	17.4	1.7	0.9	20.0	87.0	8.5	4.5

An experiment (Table 2) showed that the depth of infiltration of water into the soil changed depending upon the amount of water absorbed; with gypsum, the depth increased five to eight centimeters. The depth of soil wetting from atmospheric precipitation in the spring of 1956 on non-gypsum plots was 60 to 65 cm.; on those receiving gypsum it was 70 to 80 cm. Improvement of the permeability of solonized chestnut soils is a material factor in combating moisture in the arid Ukrainian steppe. The greater depth of wetted soil on the gypsum areas increased the supplies of available moisture in the top one-meter layer of soil by 127 cubic meters per hectare; this disclosed an increase in the supply of moisture in the deeper layers of the solonized chestnut soil. In addition to improving the water conditions, gypsum decreased the dispersion of solonized chestnut soils (Table 3) and had a positive effect on the composition of absorbed cations.

As early as the first year following application of gypsum and notwithstanding the 1953–1954 drought, the amount of calcium adsorbed in the 0 to 50 cm. layer increased by 4.0 milliequivalents per 100 grams of soil. Saturation of the adsorbing complex with calcium rose to 90 to 93%, while the quantity of adsorbed sodium and magnesium decreased (Table 4).

The quantity of water-soluble salts increased somewhat after application of gypsum, chiefly on account of the calcium salts. The perceptible accumulation of Na_2SO_4 as an exchange product was not observed after application of gypsum. The highest content of sodium salts did not exceed 0.53 milliequivalent per 100 grams of soil in the first year after gypsum (Table 5).

Deep plowing at 45 cm. in solonized chestnut soils does not attack the carbonate horizon and for this reason "self-improvement" does not take place with tillage at such a depth. The horizon at which effervescence with 10% HCl occurs lies at an average depth of 58 cm., with variations from 52 to 71 cm. With the usual plowing gypsum did not noticeably affect the depth at which effervescence took place. With deep plowing the third year after applying gypsum, the effer-

TABLE 5

Change in composition of water-soluble salts in solonized chestnut soils under the influence of gypsum

Condition of soil	Depth in cm.	As percent of air-dry soil						In me. per 100 g. of soil						
		HCO_3	SO_4	Cl	Ca	Mg	Dry residue	HCO_3	SO_4	Cl	Total anions	Ca	Mg	Na + K by diff.
Before gypsum (1953)	0–10	0.015	0.005	none	0.004	0.002	0.071	0.25	0.104	—	0.354	0.20	0.17	—
	10–20	0.010	0.006	none	0.003	0.002	0.083	0.16	0.125	—	0.285	0.15	0.17	—
	20–30	0.011	0.008	0.001	0.002	0.003	0.070	0.18	0.167	0.028	0.375	0.10	0.25	0.025
	30–40	0.013	0.009	0.001	0.003	0.003	0.072	0.21	0.188	0.028	0.426	0.15	0.25	0.026
	40–50	0.015	0.008	0.002	0.003	0.004	0.085	0.25	0.167	0.057	0.474	0.15	0.33	—
	50–60	0.028	0.008	0.003	0.005	0.004	0.088	0.38	0.167	0.085	0.632	0.25	0.33	0.049
	60–70	0.035	0.009	0.005	0.008	0.005	0.091	0.57	0.188	0.141	0.899	0.40	0.42	0.082
	70–80	0.035	0.008	0.005	0.008	0.005	0.113	0.57	0.167	0.141	0.878	0.40	0.42	0.061
	80–90	0.038	0.009	0.006	0.008	0.005	0.165	0.62	0.188	0.169	0.977	0.40	0.42	0.160
	90–100	0.029	0.013	0.008	0.007	0.006	0.129	0.48	0.270	0.225	0.975	0.35	0.50	0.125
1st year after gypsum (1954)	0–10	0.011	0.109	none	0.039	0.003	0.253	0.18	2.270	—	2.450	1.95	0.25	0.200
	10–20	0.009	0.103	none	0.032	0.002	0.242	0.15	2.150	—	2.300	1.60	0.17	0.530
	20–30	0.009	0.024	none	0.005	0.002	0.097	0.15	0.500	—	0.650	0.25	0.17	0.230
	30–40	0.012	0.008	none	0.003	0.003	0.085	0.20	0.170	—	0.370	0.15	0.25	—
	40–50	0.015	0.009	0.001	0.003	0.004	0.088	0.25	0.190	0.030	0.470	0.15	0.33	—
3rd year after gypsum (1956)	0–10	0.009	0.149	none	0.054	0.002	0.267	0.15	3.110	—	3.260	2.70	0.17	0.390
	10–20	0.009	0.123	none	0.045	0.002	0.253	0.15	2.570	—	2.720	2.25	0.17	0.300
	20–30	0.009	0.094	none	0.022	0.003	0.118	0.15	1.960	—	2.110	1.10	0.25	0.760
	30–40	0.010	0.017	none	0.030	0.004	0.103	0.16	0.350	—	0.510	0.15	0.33	0.030
	40–50	0.013	0.014	0.001	0.005	0.004	0.089	0.21	0.270	0.030	0.480	0.25	0.33	—
	50–60	0.026	0.009	0.001	0.006	0.003	0.087	0.43	0.190	0.030	0.650	0.30	0.25	0.100
	60–70	0.029	0.008	0.003	0.008	0.005	0.089	0.48	0.170	0.090	0.740	0.40	0.42	—
	70–80	0.037	0.008	0.005	0.008	0.005	0.110	0.61	0.170	0.140	0.920	0.40	0.42	0.100
	80–90	0.039	0.010	0.007	0.008	0.006	0.117	0.64	0.210	0.200	1.050	0.40	0.50	0.150
	90–100	0.038	0.015	0.007	0.008	0.005	0.142	0.62	0.310	0.200	1.130	0.40	0.42	0.310

vescence horizon went down to an average of 62 cm. with variations from 57 to 70 cm.

The improvement in the physicochemical properties of solonized chestnut soils under the influence of gypsum was favorably manifested on the density of stands of winter wheat and barley (Table 6, Figs. 2 and 3).

The yield on solonized chestnut soils increases as a result of applying gypsum, both in the first year after application and also during the two following years (Table 7).

After three years the increase in the winter wheat crop from the applied four metric tons of gypsum amounted to 4.1 to 8.4 centners per hectare. The gypsum also caused a considerable increase in the crop of raw cotton on solonized chestnut soil.

Good results were also given by gypsum on solonized chestnut soils with subsoil plowing to a depth of 42 cm. by T. S. Mal'tsev's method. The barley crop on a non-gypsum plot was 9.7 centners per hectare, but the first year after four metric tons per hectare had been applied it was 14.9 centners per hectare.

TABLE 6

Makeup of the winter wheat and barley crop according to data from selected tests of a one-square-meter area

Treatment	Winter wheat				Barley	
	First year after gypsum		Second year after gypsum		First year after gypsum	
	Number of ear-bearing stalks	Average number of grains per ear	Number of ear-bearing stalks	Average number of grains per ear	Number of ear-bearing stalks	Average number of grains per ear
Plowing 30 + 15 cm. with subsoiling	376	24.2	408	24.2	276	37.1
Same + gypsum	423	25.4	423	25.1	289	35.8
Plowing 45 cm. deep	388	20.6	453	21.9	272	31.6
Same + gypsum	390	25.1	473	23.7	293	35.2

Note. Deep tillage and subsoiling were carried out in 1953. In the following years usual plowing to a depth of 23 to 25 centimeters was done.

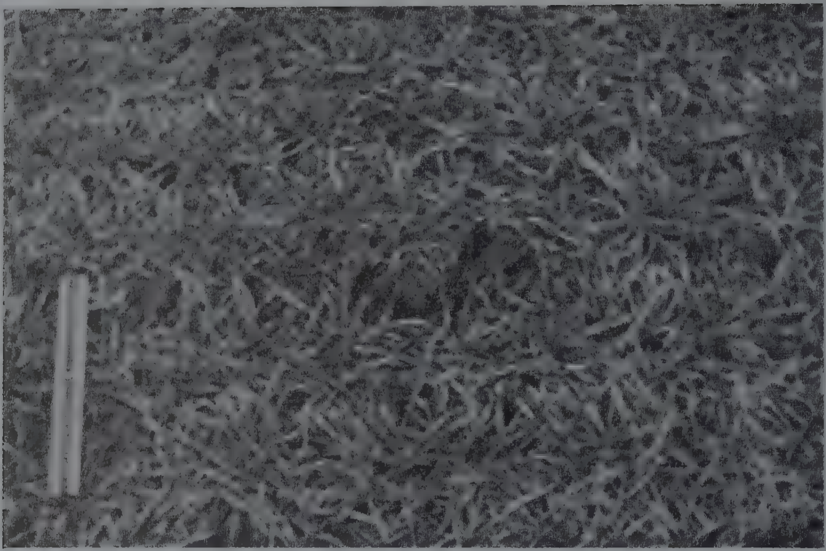

Fig. 2.—Winter wheat in the spring of 1957 on solonized chesnut soil in the fourth year after gypsum. Photograph by the author.

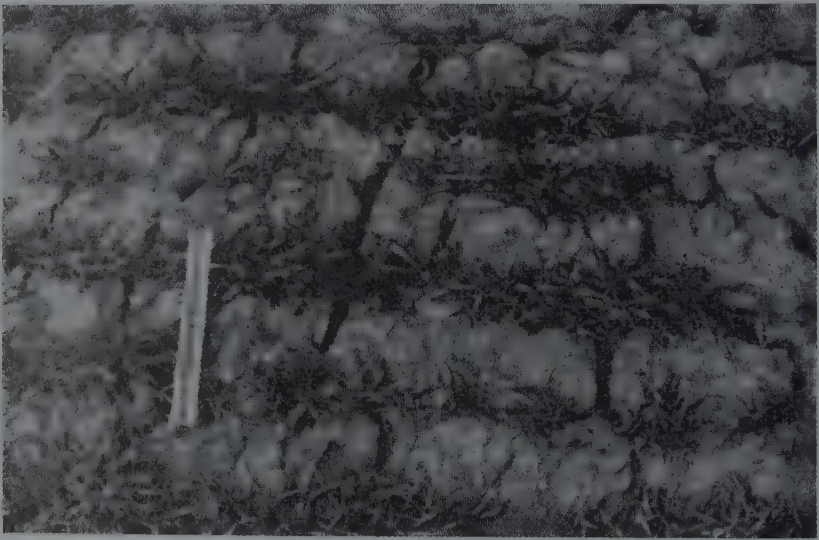

Fig. 3.—Winter wheat in the spring of 1957 on solonized chesnut soil without gypsum. Photograph by the author.

Applying four metric tons per hectare of gypsum on dark, solonized chestnut soils on the Voroshilov Collective Farm, Skadovsk district, Kherson region, with tillage to a depth of 18 to 20 cm., increased the winter wheat harvest the second year after gypsum by 5.1 centners per hectare; plowing to a depth of 30 cm. gave a 2.2 centner per hectare increase. On the Chervonii Selyanin collective farm, Kalanchak district, Kherson region, applying gypsum at the same rate increased the winter wheat crop the same year by 5.1 centners per hectare when

TABLE 7

Winter wheat and barley crop on solonized chestnut soil in centners per hectare (according to data from fractional calculation)

Treatment	Winter wheat			Barley
	First year after gypsum	Second year after gypsum	Third year after gypsum	First year after gypsum
Plowing at 30 + 15 cm. subsoiling	12.4	25.8	9.8	18.1
Same + 4 metric tons per hectare of gypsum	14.0	27.6	10.3	18.6
Plowing at 45 cm.	10.7	25.7	10.0	16.8
Same + 4 metric tons per hectare of gypsum	13.8	28.6	12.4	18.6

Note. Deep tillage at 45 centimeters and plowing with subsoiling were done in 1953. In the following years usual plowing was carried out at 23 to 25 centimeters.

plowing took place at a depth of 18 to 20 cm. (7).

In view of the future irrigation by the Krasnoznamensk irrigation system of large areas of solonized chestnut soils in the southern Ukraine, we must start *now* to devoting thought to improving those properties of these soils which are of agricultural importance: the principal task is increasing their permeability to water, which may be accomplished successfully by the use of gypsum. Application of gypsum on solonized chestnut soils together with irrigation, will greatly increase the yields of crops. According to M. F. Budanov's data (1), the yield of raw cotton grown on moderately- and strongly-solonized chestnut soils was increased from the use of gypsum by 3.1 to 7.5 centners per hectare with three waterings.

Conclusions

1. Gypsum improves the physicochemical properties of solonized chestnut soils and increases the yields of crops for a period of years.

2. On solonized chestnut soil complexes where spots of solonetz are present, gypsum must be applied not only to the spots, but must be broadcast evenly by a fertilizer spreader over the entire area. Gypsum is applied at a differential rate depending on the degree of solonization and the number of solonetz spots on each field.

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CHARACTERISTICS OF IRRIGATED ALLUVIUM SOILS ON THE SAMARKAND OASIS

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IRRIGATED agriculture almost always involves the delivery by the irrigation water of fairly considerable quantities of dissolved and solid substances to the fields (2, 3, 5, 6, 8, 9). It is natural that a question should arise as to their importance in the fertility of the irrigated soils.

Our investigation of irrigated alluvial soils in the Samarkand oasis was planned to study its chemical and physical properties, mineral composition, and the character of its delivery and distribution on the fields for the purpose to maintain and increase the fertility of the irrigated soils.

The source of water for the Samarkand oasis is the Zeravshan river. Like many rivers of Central Asia, the Zeravshan is supplied by melting snow and glaciers and is characterized by extended periods of flooding: from May to July by melting snow and from July to August by melting glaciers. Almost the entire volume of the river is used for irrigation. The sediments of the Zeravshan river have scarcely been studied. We have only some data from hydrological investigations of the discharge and hydrochemical composition of the river water (at Dupuli). Determinations have also been made of the particle size of the sediments, but they cannot be considered completely satisfactory since fractions less than 0.01 mm. in size were not broken down any further; this is clearly inadequate for evaluation of the physical properties (1, 7).

Characteristics of the discharge, turbidity, and mineralization of the Zeravshan waters are shown in Table 1, which was based on data derived from the Hydrological Annual for 1947. The maximum discharge and sediments of the Zeravshan were observed from June to August. The discharge of the three summer months amounted to 81% of the total annual flow. From May to August mineralization of the water of the Zeravshan was 0.175 grams per liter; the rest of the time it was 0.22 grams per liter.

The quantity of sediments transported by the river was 4,500,000 metric tons per year. This is enough to form a layer 1 m. thick on an area of about 350 ha. Ultimately almost all the sediment flows with the water onto the fields. In addition, 828,000 metric tons of dissolved substances are also brought in, including 250,000 of calcium, 33,000 of magnesium, 25,000 of potassium, 21,000 of sodium, 33,000 of water-soluble humus, 1,500 of nitrogen, and 1,250 metric tons of phosphorus (as P_2O_5). Thus, about 5,500,000 metric tons of sediments and dissolved substances reach the irrigated fields of the Samarkand and Bukhara oases.

The presence of a flow of solid material in river waters is caused by erosion in the catchment basin. The amount of erosion caused by the Zeravshan in the mountainous part of its course is 500 to 1000 metric tons per year from one square kilometer. The high rate of removal from the drainage area is explained by the wide distribution here of Silurian metamorphic schists and sandstones, which are quite subject to denudation and weathering, by the high average altitude of the basin and by the very steep slopes of the Turkestan and Zeravshan ranges between which the narrow river valley of the Zeravshan is located (11). The strongly pronounced irregularity of the surface of the ranges and a rather considerable amount of atmospheric precipitation also increase the erosion rate. The increased turbidity of the upper and middle courses of the river is due to the high rate of deep erosion with the pulverization of bottom alluvium.

Experimental Part

Investigation of Sediments. Changes in the sediment and its distribution in different parts of the irrigation system were followed, beginning with the river and ending with the irrigation ditches. Samples of sediments were collected in 1954 in the river and canals from a depth of 50 cm. below the surface with a bathometer; in shallow laterals of the irrigation system they were collected with buckets or dippers. Then the suspended matter was allowed to settle and was filtered off. The amount of sediments and its distribution in various parts of the irrigation system are given in Table 2.

Table 2 shows that the quantity of sediments

TABLE 1

Discharge of water, suspended and dissolved substances in the Zeravshan river
(Observations from 1914 to 1945; measured at Dupuli)

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Discharge, M³/sec.	36.1	34.3	37.0	57.0	196	362	438	347	187	87	54	43
Turbidity, g./M³	32	29.0	70	157	967	868	1466	1363	520	108	53	36
Quantity of sediments delivered per month (thousands of metric tons)	3.2	2.3	6.4	26.0	488.8	816.4	1570.4	1229.8	252.2	23.4	7.5	4.8
Quantity of dissolved substances (thousands of metric tons)	41.0					575.3			212.1			

in analogous links of the irrigation system, but in different systems, is not the same. Thus, at Dargom the water was twice as turbid as at Bulungur. About the same difference was observed in corresponding laterals and ditches. This is due to the fact that the Dargom canal is of recent construction, carries a large quantity of water (80 to 120 cubic meters per second) and has a greater slope than the Bulungur canal, which is heavily silted and carries several times less water. This is reflected in other links of the irrigation system. The greater turbidity of the water in the Dargom canal as compared with that of the Zeravshan river is probably related to the fact that the Dargom flows over and erodes loess deposits on its course, while the Zeravshan flows over a stony bed. The table shows a regular pattern in the distribution of sediment in the different parts of the irrigation system. Thus, in the Dargom system, the turbidity in the Dargom itself is 3.24 grams per liter, in the lateral canals it decreases to 2.2 and in the irrigation ditches to 1.92. In the Bulungur canal the turbidity is 1.55 grams per liter, decreasing in the laterals to 1.31 and in the irrigation ditches to 1.20. Thus, while the water is passing from the main canal to the irrigated field, 22.6 to 40.7% of the sediment is deposited. Despite the considerable amount of deposition of sediment in the canals, 10.8 to 17.9 metric tons of suspended matter is brought to the fields every year, producing an annual increase in the thickness of the tillage horizon of 0.8 to 1.3 mm. As a result, a new tillage horizon, 20 cm. thick, can be formed in 150 to 200 years; its properties will be determined by the quality of the irrigation deposits.

TABLE 2

Quantity of sediment and its distribution

Link of irrigation system	Date sample taken	Amount of sediment, gm./l.	Amount which can reach fields in metric t./ha. with irrig. rate of 9000 M³/ha.
Zeravshan	Aug. 5	2.52	22.7
Main irrigation canal, Dargom	Aug. 7	3.24	29.1
Lateral canal	Aug. 7	2.20	19.8
Irrigation ditch	Aug. 7	1.92	17.9
Main irrigation canal, Bulungur	Aug. 6	1.55	13.9
Lateral canal	Aug. 6	1.31	11.8
Irrigation ditch	Aug. 6	1.20	10.8

The particle size of the sediment, as may be seen from Table 3, is extremely varied in different links of the irrigation system. With branching and prolongation of the irrigation system, the particle size of the sediment becomes finer-textured. The sediment possessing the finest texture is found in the irrigation ditches. The proportion of particles less than 0.01 mm. in diameter in the ditch near section 1 reaches 74%, while the greatest proportion of these particles in the laterals reaches 53%, and in the main canals only 45%. Almost no differences are observed in the texture of sediments of analogous links in the irrigation systems. Only the sediment in the lateral and irrigation ditch near soil section 1 was significantly finer-texture than in analogous links in other irrigation tracts and systems. This is due to the abrupt change in slope of the course of the lateral as compared with that of the main canal, resulting in the deposition of a high proportion of large particles at the point of exit from the main canal; part of them, how-

TABLE 3

Particle-size analysis of sediment in different irrigation systems of the Samarkand oasis by Kachinskii's method (Analyses by G. I. Mel'nikov)

Place sample taken	$CaCO_3$ %	Quantity of particles as percent; diameter in millimeters						
		>0.25	0.25–0.1	0.1–0.01	0.01–0.005	0.005–0.001	<0.001	<0.01
Zeravshan	13.06	0.24	3.25	55.68	12.48	15.17	13.18	40.83
Dargom canal, near section 3	15.01	0.47	10.49	44.26	12.44	17.60	14.74	44.78
Lateral canal near section 3	13.0	2.92	11.96	41.91	12.43	16.55	14.23	43.21
Irrigation ditch near section 3, Dzhuma station	14.56	0.19	1.84	50.60	14.27	20.80	12.30	47.37
Dargom canal, near section 1	13.31	0.94	14.20	39.16	14.22	18.31	13.17	45.70
Lateral canal near section 1	12.01	0.16	0.33	45.61	14.82	18.68	20.40	53.90
Irrigation ditch near section 1, Komsomolsk district	15.30	—	0.20	25.51	18.39	26.84	29.06	74.29
Palvan canal near section 62	12.8	—	10.22	51.62	12.54	13.53	12.09	39.16
Lateral canal near section 62	15.20	—	14.47	48.98	10.86	12.14	13.55	36.55
Irrigation ditch near section 62, Bulungur district	13.36	—	2.31	41.60	15.60	22.44	18.05	56.05

TABLE 4

Particle-size analysis of irrigated cultivated horizons of irrigated soils (by N. A. Kachinskii's method)

Section no.	Depth cm.	$CaCO_3$ %	Quantity of particles as pecent; diameter in millimeters						
			1–0.25	0.25–0.1	0.1–0.01	0.01–0.005	0.005–0.001	<0.001	<0.01
1	0–20	13.80	0.32	14.30	44.26	11.60	15.36	14.16	41.12
	55-65	14.13	0.58	22.49	44.38	8.88	11.72	11.95	32.55
62	0–5	13.55	0.16	2.84	42.80	13.44	18.68	22.18	54.30
	15–85	13.50	0.42	7.05	42.37	12.12	15.64	22.40	50.16
3	0–5	14.10	13.77	17.36	35.63	9.94	11.30	12.0	33.24
	22–32	13.80	8.43	16.54	42.98	9.41	9.97	12.67	32.05
55	0–5	15.39	0.71	11.40	50.17	10.34	9.75	17.63	36.82
	5-15	15.68	0.75	11.70	50.05	9.55	10.75	17.20	37.60

ever, go over into the cohesive state and move down to the bottom of the lateral.

In the succeeding links of the irrigation system the texture of the sediment tends to become finer because of the deposition of the large particles while being transported from the main canal to the irrigated field. Thus, the sediment of the Dargom canal near section 3 contained 10.96% of the particles between 1 and 0.1 mm. in size. Only 2.03% of the particles of the sediment of the irrigation ditch near section 3 were of this size, while the total proportion of the particles less than 0.01 mm. in diameter increased from 44.78 to 47.37%. An even more graphic picture is seen in the Palvan system and in the Dargom canal near section 1.

Determinations of soil texture from the thick irrigation horizon (Table 4) showed that continuously irrigated soils were considerably coarser than the sediment in the irrigation ditches (Table 3). Sediment deposited on the fields (section 1) contained up to 23% of the particles greater than 0.1 mm. in diameter, while the sediment in the irrigation ditches contained only 1.2% of them. The difference in the texture of deposited particles (section 3) and sediment in the channel near this section is even more noticeable. Particles larger than 0.1 mm. in diameter constituted 1.2% of the sediment, but 25 to 31% of the deposits. Particles larger than 0.25 mm. in diameter were not detected in the sediment of the ditches, whereas they constituted 13% of the deposited sediment. This made it possible to conclude that there is a different method of delivery of irrigation sediment. To this end we took samples of cohesive sediment, investigation of which confirmed its delivery to the field. The quantity delivered was 1 to 1.5 metric tons per hectare per year.

Chemical Composition of Sediment. To characterize the chemical composition of the sediment, a complete analysis was done on that from the Zeravshan river. For purposes of comparison, Table 5 also gives data on the chemical composition of sediment from the Amu Darya and Syr Darya rivers (10).

Table 5 indicates that there is 2.4 to 7.1% more SiO_2 in the sediment of the Zeravshan river than in the sediment of the Amu Darya and the Syr Darya. With respect to total R_2O_3 content of the sediment, the three rivers are fairly uniform; however, the Zeravshan sediment contains almost twice as much Fe_2O_3, 2 and 3.9% less CaO, and 2 and 1.8 times as much MgO as the sediment of the Amu Darya and Syr Darya, respectively. A comparison of the contents of elements most important in soil fertility shows that Zeravshan sediment contains

TABLE 5

Chemical composition of sediment from the Amu-Dar'ya, Syr-Dar'ya and Zeravshan rivers

River	Date	As percent of ovendry weight								
		SiO_2	R_2O_3	Fe_2O_3	Al_2O_3	P_2O_5	CaO	MgO	K_2O	Na_2O
Zeravshan	8/3/54	52.40	18.88	5.07	13.53	0.18	10.81	3.44	2.47	1.76
Syr-Dar'ya	7/3/50	45.32	17.50	2.43	14.99	0.08	14.70	1.94	1.35	2.34
Amu-Dar'ya	7/18/50	50.00	17.60	2.47	15.00	0.13	12.00	1.81	1.21	1.64

2.1 and 1.5 times as much P_2O_5 and 1.9 and 2.1 times as much K_2O as the sediment of the Amu Darya and Syr Darya rivers. To characterize the quantities of substances reaching the soil by irrigation with Zeravshan water, determinations of them were made (Table 6). These data show that Zeravshan water brings to the soil a significant amount of Ca^{++} and K^+ (about the same quantity as that brought by the water of the Amu Darya and the Syr Darya) and somewhat (two to four times) less Cl^- and $SO_4^=$. Thus, Zeravshan water, notwithstanding its lower turbidity as compared to the Amu Darya and the Syr Darya, furnishes the fields with as large a quantity of nutrient elements as by those of the Amu Darya or Syr Darya. At the same time Zeravshan water contains considerably less easily soluble salts.

Mineralogical Composition of Sediment and of Ordinary Sierozem. To clarify the question of how the mineralogical composition of soils changes with irrigation, we carried out quantitative determinations on immersion preparations of the minerals of Zeravshan sediment, and also on sediment in all the parts of the irrigation system. For purposes of comparison a mineralogical analysis of ordinary sierozem on loess was also done (section 4). The 0.25–0.1 mm. and 0.10–0.01 mm. diameter fractions, previously prepared by the method of N. I. Gorbunov, were subjected to analysis.

From Table 7 it is seen that the content of heavy minerals in the 0.25–0.1 mm. diameter fraction of sediment from different links of the irrigation system decreases abruptly, beginning with the main irrigation canal (26.7) and going down to the lateral (14). This is due to the fact that primarily the heavier ore minerals and amphiboles are deposited while the sediment is being transported. The heavy minerals of the 0.25–0.1 mm. diameter fraction are chiefly micas, ore minerals (limonite) and amphiboles. The light minerals of the 0.25–0.1 mm. diameter frac-

TABLE 6

Quantities of some substances reaching the soil by irrigation in kilograms per hectare (irrigation rate, 9000 cubic meters per hectare)

River	In sediment			In irrigation water			
	$CaCO_3$	K_2O	P_3O_5	K^+	Ca^{++}	$SO_4^=$	Cl^-
Zeravshan	2350	485	41	45	680	198	90
Amu-Dar'ya	4190	422	45	45	675	774	360
Syr-Dar'ya	1300	119	7	54	549	792	198

TABLE 7

Mineralogical composition of sediment of the Samarkand oasis (as percent of the fraction)

Minerals	Zeravshan		Main irrigation canal		Lateral canal		Irrigation ditch	
	Fractions by particle diameter in millimeters							
	0.25–0.1	0.1–0.01	0.25–0.10	0.1–0.01	0.25–0.1	0.1–0.01	0.25–0.1	0.1–0.01
Heavy Fraction								
Specific gravity >2.72	20.8	23.6	22.7	24.2	14.0	22.0	14.2	22.6
Biotite	2.8	5.7	2.1	7.1	1.8	4.4	2.1	4.3
Muscovite	2.6	10.8	2.0	8.8	0.9	9.9	1.5	10.8
Hornblende	2.1	3.8	1.4	4.1	1.8	4.0	1.0	3.5
Ores	6.6	0.6	7.8	0.6	4.3	0.6	5.0	0.7
Rock fragments	5.1	1.5	8.8	0.7	4.7	0.5	4.4	0.3
Minerals covered by iron hydroxides	0.6	0.3	0.6	2.0	0.5	1.9	0.2	2.0
Granite, epidote, zircon, titanite etc	few	0.9	few	0.9	few	0.7	few	1.0
Light fraction								
Specific gravity <2.72	79.2	76.4	77.3	75.8	86.0	78.0	85.8	77.4
Quartz	27.1	27.5	32.5	28.9	35.5	31.7	32.4	28.6
Feldspars	9.6	12.3	8.2	12.8	10.3	13.9	11.5	12.0
Rock fragments	42.7	36.5	36.6	34.1	40.2	32.4	41.9	36.8
Quartz-Feldspars ratio	2.8	2.2	3.9	2.3	3.4	2.3	2.8	2.3

TABLE 8

Mineralogical analysis of a typical sierozem on loess (virgin soil) of Samarkand oasis as percent of the fraction

Minerals	Horizons in centimeters							
	0–10		35–45		130–140		240–270	
	Fractions by particle diameter in millimeters							
	0.25–0.1	0.1–0.01	0.25–0.1	0.1–0.01	0.25–0.1	0.1–0.01	0.25–0.1	0.1–0.01
Heavy fraction								
Specific gravity >2.72	11	17.2	14.5	17.4	25.5	20.1	29.7	19.9
Biotite	2.7	4.8	6.5	5.9	11.8	6.7	17.0	6.4
Muscovite	0.6	6.4	2.2	4.9	6.5	6.2	7.8	5.8
Hornblende	0.8	1.6	0.7	2.5	0.8	3.0	0.9	3.4
Ores	3.5	1.6	2.6	1.3	2.9	1.6	2.1	1.6
Rock fragments	3.4	1.5	2.5	0.3	3.5	0.9	1.9	0.9
Accessory minerals	few	1.3	few	2.5	few	1.7	few	1.8
Light Fraction								
Specific gravity <2.72	89.0	82.8	85.5	82.6	74.5	79.9	70.3	80.1
Quartz	41.2	31.2	31.3	28.1	26.2	31.8	26.0	30.5
Feldspars	18.9	12.0	11.4	16.8	12.0	18.2	14.1	17.4
Rock fragments	28.9	35.8	42.8	36.9	36.3	29.4	30.2	31.6
Fossil plants	—	3.8	—	0.8	—	0.5	—	0.6
Quartz-feldspars ratio	2.2	2.6	2.7	1.7	2.3	1.8	1.8	1.7

tion are quartz and feldspars and also rock fragments: metamorphic schists, sandstones and quartzites, more or less permeated with oxides of iron and aluminum. Sometimes, inclusions of apatite, rutile, and tourmaline are found in the minerals entering into the composition of the rock fragments.

In the 0.10–0.01 mm. diameter fraction the heavy minerals amount to 25 to 27%, with negligible variations in the different links of the irrigation system. The heavy minerals of the 0.1–0.01 mm. fraction are more variegated than in the 0.25–0.1 mm. fraction. Here we occasionally find such minerals as epidote, zoisite, and zircon, which are lacking in the 0.25–0.1 mm. fraction. Most of the heavy part of the 0.1–0.01 mm. fraction consists of micas (chiefly muscovite), limonite and amphiboles (colorless and faintly colored). The light minerals of 0.01–0.1 mm. fraction are quartz, rock fragments, and occasional fossil plants. The feldspars are orthoclase, microcline, and more rarely oligoclase and acid plagioclases.

For determining the mineralogical composition of sierozem on loess, samples were taken from depths of 0 to 10, 35 to 45, 130 to 140, and 240 to 270 cm. The results are shown in Table 8.

The content of heavy minerals in the 0.25–0.1 mm. diameter fraction changes strongly along the soil profile, increasing with depth from 11 to 29.7% of the weight of the fraction. The minerals are chiefly micas (mostly biotite), hornblendes, ore minerals and sericite. The 0.25–0.1 mm. loess fraction contains less hornblendes than the sediment does.

The light fraction contains fragmented minerals, quartz and feldspars, many of the latter being sericitized. The feldspare content is the same as that of sediment. The content of heavy minerals in the 0.1–0.01 mm. fraction increases with depth from 18.2 to 21.9%. The heavy minerals of this fraction are also micas with a considerable predominance of biotite over muscovite (except in the 0–10 cm. horizon, where muscovite predominates), hornblendes and zoisite. Rarely, but still more often than in sediment, minerals such as titanite, garnet, zircon, tourmaline and apatite are encountered. Sierozem on loess contains 20% less heavy minerals in the 0.1–0.01 mm. fraction than does sediment. The light minerals of the 0.1–0.01 mm. fraction are quartz, rock fragments and feldspars (orthoclase, microcline, and rarely plagioclases).

A comparison of the mineral content of sediment and of sierozem on loess shows the following: The heavy minerals of the 0.25–0.1 and 0.1–0.01 mm. fractions, both of loess and of sediment, consist chiefly of micas. With respect to heavy mineral content, sediment contains 15 to 20% more than does loess, chiefly hornblendes and muscovite. In suspended alluvium, muscovite predominates over biotite; in loess, this is reversed and biotite predominates over muscovite. The presence of large quantities of rock fragments both in loess and in sediment is noteworthy. The ratio of quartz to feldspars in virgin sierozem on loess is considerably smaller than in sediment, except in the upper 0 to 10 cm. horizon of the sierozem.

Conclusions

1. Irrigation water and sediment furnish nutritive elements in a form which is accessible to plants. Irrigation water plays an especially large part in the supply of potassium. Irrigation sediment contains a considerable potential supply of nutritive elements.

2. When irrigation with sediment takes place, the supply of heavy minerals, which contribute greatly to fertility, is greater than that of loess; however, in the lower horizons of virgin sierozem there are more feldspars than in sediment.

3. Those using irrigation for agricultural purposes should strive to have the sediment delivered to the irrigated fields and prevent it from silting up the irrigation system.

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SOILS UNDER SPRUCE FORESTS OF THE CARPATHIANS

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THE conditions of soil formation in the Carpathians are like those of the zone of beech and coniferous forests of Central Europe, the Crimea and the Caucasus where, as investigations by a number of authors have shown, soils of the brown earth type develop predominantly.

The Carpathian soils have been studied by G. A. Andrushenko (1, 2), N. B. Vernander (3) and others.

Under spruce forests, as has been established by L. I. Prasolov (7, 8), B. D. Zaitsev (6), S. V. Zonn (5) and others, typical brown earths are not formed. S. V. Zonn (5) suggests that in spruce forests, as a result of the high acidity of the coniferous needles, a part of the ash elements is very quickly removed from the upper horizons together with the water-soluble acids. This may apply especially to SiO_2 which is leached out from the litter and descends to the upper mineral horizon, lending it a pronounced appearance of being podzolized. This can be confirmed.

B. D. Zaitsev (6), referring to the definite characteristics of the podzol-forming process under spruce (removal of cations from the upper horizons and the accumulation of silicic acid there, as well as their acid reaction), notes a certain specificity of podzolized brown earths in comparison with typical podzolized soils: the great thickness of the humus-podzolized horizon (A_1) in them with the presence of a fairly considerable quantity of humus, a clearly manifested accumulation of calcium, and the presence of a clearly expressed nut-like to granular structure.

In order to study soil conditions on growing spruce forests, thirty-two soil sections and other samples were taken for chemical and particle-size analysis on test areas in spruce stands of various sizes and under different conditions of local growth in the plantations of the Zakarpatskaya and Stanislavskaya regions.

The distinguishing characteristics of the soils we investigated are: 1. Brown color of the entire profile with some lightening of horizon A_2. 2. Almost complete absence of redistribution of the clay fraction in the soil profile. 3. High acidity. 4. Thin soil with considerable inclusion of fragments of clayey schists and sandstones. 5. The presence of a well-developed lumpy structure, especially in the upper horizons.

Soil qualities suitable for plantations changed materially depending on the altitude above sea level, exposure, and steepness of the slopes. Soils most favorable for the growth of spruce formed at altitudes of 700 to 1050 m. above sea level on northern and southern slopes slanted as much as 20° and in young fir and humid fir-beech forests. These soils are 70 to 80 cm. thick, covered by a 4 to 5 cm. layer of litter which is easily decomposed. There is a well-developed lumpy structure in all horizons and a large number of earthworms.

The parent material is usually clayey schists, sometimes with an admixture of sandstones. Texture is intermediate, less often clay loam. They have a relatively high degree of saturation by cations (see Table 1). The amount of mobile potassium and phosphorus is small in all the soils investigated, but in the young fir and moist fir-beech types of forest these elements, which are important for the growth and development of spruce, are relatively abundant. A very low ratio of carbon to nitrogen is also characteristic of these soils. In horizon A_1 this ratio is 10 to 11; in horizon B it is 6 to 8, showing the rapid decomposition of organic matter and the formation of soft humus. Site quality of 1^b spruce is on such soils.

High productivity for spruce is observed on soils formed at altitudes of 1000 to 1100 m. above sea level on northern slopes up to 25° to 28° in sparse forests of the moist fir type. Here the soil is about 60 to 70 cm. thick and decomposition of the organic matter also takes place at a high rate. This soil is composed of medium and fine-textured clay loams (see Table); in all horizons there are large amounts of sandstone and schist fragments. The degree of saturation with cations of these soils in the upper horizons is somewhat lower (30 to 35%) than in coniferous forests; there is also a decrease, although to a small degree, in the amount of mobile potassium and phosphorus. Site quality of spruce is 1^a.

At an altitude of 1000 to 1200 m. above sea level, on southern 33° to 37° slopes under young,

TABLE 1

Data from chemical and particle-size analyses of the soils investigated

Section No.	Plantation, forest type	Altitude (M) exposure, slope angle	Horizon	Depth of sample, cm.	Humus, %	pH		Hydrolytic acidity me./100 g. soil	Total absorbed cations, me./100 g. soil	Degree of saturation by cations, %	Mobile K, mg./100 g. soil	Mobile P_2O_5, mg./100 g. soil	Total N as %	Particle-size analysis					
						Saline extract	Water extract							Quantity of particles in % Diameter in millimeters					
														1–0.25	0.25–0.05	0.05–0.01	0.01–0.005	0.005–0.001	0.001 & <
23	Rakhovskii, young fir	1020 S. E. 18°	A_1	5–10	5.41	4.7	5.4	5.24	3.05	36.8	0.493	0.041	0.314	10.56	27.52	26.25	7.58	15.36	12.73
			A_2	20–25	4.06	4.5	5.3	3.74	1.72	31.5	0.406	0.032	0.282	11.23	28.46	24.46	9.36	14.21	12.28
			B	50–55	2.22	4.6	5.4	3.21	1.02	24.2	0.248	0.031	0.154	10.24	30.84	23.24	8.46	18.24	8.98
			C	70–75	1.04	4.6	5.4	2.65	0.69	20.8	0.116	0.022	0.105	13.21	27.26	22.58	7.64	13.62	15.69
7	Rakhovskii, moist young fir-beech	880 N. 18°	A_1	5–10	4.86	4.8	5.6	4.52	3.32	42.4	0.519	0.056	0.249	6.56	31.49	20.51	10.32	16.36	14.76
			A_2	20–25	3.21	4.8	5.5	4.01	2.22	35.6	0.415	0.042	0.218	7.38	33.54	19.66	8.52	18.24	12.66
			B_1	50–55	2.12	4.7	5.5	3.26	0.84	20.5	0.276	0.031	0.183	8.96	32.82	17.35	9.63	16.56	14.68
			B_2	70–75	1.36	4.8	5.6	2.71	0.78	22.4	0.166	0.024	0.160	8.54	32.78	16.84	7.56	15.43	18.85
19	Rakhovskii, moist young fir-beech	900 N., E. 14°	A_1	5–10	5.36	4.7	5.6	4.37	3.61	45.1	0.723	0.051	0.260	9.38	36.42	19.83	8.67	15.44	10.26
			A_2	20–25	4.12	4.8	5.6	4.65	2.80	37.5	0.521	0.034	0.282	8.65	35.54	19.21	7.94	20.34	8.32
			B_1	40–45	3.24	4.5	5.5	3.77	1.12	22.6	0.418	0.018	0.209	10.12	36.83	20.44	8.53	16.24	7.84
			B_2	60–65	1.86	4.7	5.6	2.41	0.80	26.5	0.201	0.020	0.127	10.46	37.24	21.55	9.34	14.30	7.11
36	Nadvoryanskii, recent clean sparse	1120 S. 34°	A_1	5–10	8.06	4.2	4.9	6.34	1.96	23.6	0.319	0.021	0.265	23.56	36.58	15.26	4.54	7.26	12.8
			A_2	20–25	4.64	4.4	5.1	5.42	1.48	21.5	0.115	0.020	0.192	24.29	36.29	15.34	5.43	7.34	11.33
			B	40–45	2.42	4.5	5.2	4.11	0.77	15.9	0.094	0.018	0.110	22.51	34.56	18.14	4.27	8.21	12.31
87	Delyatinskii, recent clean sparse	1100 S.W. 37°	A_1	5–10	7.28	4.3	5.1	5.96	2.02	25.3	0.327	0.026	0.233	25.31	38.56	15.36	3.54	6.72	10.51
			A_2	20–25	4.04	4.5	5.2	5.12	1.34	20.8	0.214	0.023	0.151	24.45	37.24	12.94	4.29	7.31	12.77
			B	40–45	1.86	4.6	5.2	3.14	0.66	17.5	0.118	0.024	0.072	21.29	32.53	16.22	4.58	7.51	17.88
25	Teresvyanskii, moist fir, sparse	1040 S. 26°	A_1	5–10	6.21	4.5	5.1	4.82	2.31	32.4	0.470	0.031	0.263	7.34	38.42	22.52	10.24	16.57	4.91
			A_2	20–25	4.34	4.5	5.0	3.36	1.10	24.6	0.422	0.025	0.244	9.26	36.54	21.42	8.36	19.11	5.31
			B	50–55	2.82	4.7	5.1	2.71	0.89	24.8	0.315	0.027	0.162	8.42	34.22	24.54	7.92	17.24	7.66
			C	70–75	0.84	4.6	5.1	2.04	0.62	18.9	0.323	0.017	0.062	10.44	35.21	22.37	8.35	17.25	6.38
112	Rakhovskii, moist, clean young	1120 N.E. 25°	A_1	5–10	7.93	4.3	4.9	6.12	1.99	24.6	0.435	0.034	0.276	18.21	33.29	16.36	8.37	5.64	18.13
			A_2	20–25	6.22	4.5	5.1	5.74	1.46	20.3	0.344	0.027	0.267	17.34	35.31	19.24	9.43	6.21	12.47
			B	50–55	2.43	4.6	5.2	3.31	0.45	12.2	0.368	0.020	0.143	16.26	35.46	19.22	6.52	5.23	17.31
139	Nadvoryanskii, moist sparse fir	1080 S.E. 27°	A_1	5–10	7.48	4.4	5.0	5.76	3.20	35.5	0.522	0.041	0.340	16.84	36.66	15.39	8.60	5.67	16.83
			A_2	20–25	5.74	4.3	5.0	5.24	1.83	25.5	0.446	0.036	0.312	17.34	33.42	18.46	7.83	7.71	15.24
			B	40–45	5.23	4.6	5.2	4.47	1.61	26.3	0.312	0.021	0.365	14.18	32.93	19.41	6.12	8.00	19.36
			B	50–55	2.11	4.6	5.3	3.04	0.80	20.7	0.218	0.021	0.174	17.22	34.26	17.34	9.16	6.31	15.71
58	Nadvoryanskii, wet, clean sparse	1210 N. 23°	A_1	6–10	7.58	4.0	4.8	6.48	1.20	15.6	0.349	0.036	0.211	15.24	36.44	16.52	9.46	6.34	15.8
			A_2	20–25	5.04	4.1	4.9	5.32	0.68	11.4	0.302	0.011	0.161	16.43	34.22	17.45	7.98	8.31	15.61
			B	40–45	2.02	4.1	5.0	3.21	0.39	10.8	0.421	0.020	0.075	15.21	33.47	17.28	8.35	8.27	17.42
									0.70	6.7	0.306	0.027	0.236	17.36	44.53	18.12	4.82	8.47	6.70
63	Nadvoryanskii, young spruce-pine	1360 S.W. 38°	A_1/A_2	5–10	9.46	4.1	4.8	9.64	0.32	3.4	0.312	0.012	0.194	19.10	43.21	16.38	6.71	5.32	9.28
			B	15–20	6.24	4.3	5.0	8.36	1.01	10.2	0.314	0.032	0.241	15.94	46.81	14.24	7.92	5.23	9.86
91	Nadvoryanskii, moist spruce-pine	1380 E. 36°	A_1/A_2	5–10	10.24	4.2	5.0	8.74	0.60	6.88	0.305	0.024	0.224	18.36	45.34	15.58	7.12	5.66	7.94
			B	15–20	7.76	4.2	5.0	8.11											

clean, scanty types of forests, an even thinner material develops (50 to 55 cm.). Particle-size analysis shows fine-texture clay loams or sandy loams with a considerable content of sandstone fragments. The degree of saturation with cations falls to 23 to 25% in the upper horizons; there is also less mobile potassium and phosphorus than in dark-needled spruce forests and moist, scanty forests. The growth of spruce is slower on such soils and productivity is decreased to site quality II.

At altitudes of 1200 to 1250 m. above sea level on northern 20° to 25° slopes under moist, clear, sparse forests, the soil is 50 to 60 cm. thick and the litter reaches thicknesses of six to seven cm. and more; organic matter is decomposed slowly here as a result of excessive moisture and insufficient air in the soil. The ratio of carbon to nitrogen in the upper mineral horizon of these soils reaches 20 to 21. The site quality of the spruce grown on such soils goes down to III.

At altitudes of 1300 to 1400 m. above sea level under colder and more moist climatic conditions on steep (35 to 40°) slopes under spruce groves of the recent, moist sparse coniferous material, thin soils (up to 20 to 30 cm.) are formed; particle-size analysis usually shows sandy loams or fine-textured clay loams (see Table) with coarse humus; their carbon-to-nitrogen ratio is 23 to 25 and they have a very low degree of saturation with cations, 7 to 10%. Site quality IV spruce stands are grown on them.

Conclusions

1. Under spruce forests in the Carpathians, brown earths develop. Their distinguishing characteristics are: a) brown color of the entire profile, somewhat lighter in the A_2 horizon; b) an almost complete absence of redistribution of the clay fraction in the profile; c) high acidity; d) a thin layer of soil with substantial inclusions of fragments of clayey schists and sandstones; e) the presence of a well-developed lumpy structure.

2. Depending on the altitude above sea level, the orientation of the exposure, and the steepness of the slopes, the soils are characterized by varying site qualities. The most favorable conditions for the growth of spruce are at an altitude of 700 to 1100 m. above sea level on the more slanting (up to 20°) northern slopes. The soils here attain thicknesses of 70 to 80 cm. and are distinguished by a maximum degree of saturation by cations (40 to 45%). They are usually medium clay loams.

With increases in the altitude and steepness of the slopes, soil qualities become less favorable for spruce. At altitudes of 1300 to 1400 m. above sea level, under colder and more moist climatic conditions, on steep (35 to 40°) slopes very thin (up to 20 to 30 cm.) soils develop, usually coarsely humus sandy loams with cation saturation not more than 7 to 10%.

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EFFECT OF CONTINUOUS APPLICATION OF FERTILIZERS ON THE PROPERTIES OF KRASNOZEMS AND THE PRODUCTIVITY OF TEA PLANTATIONS

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TEA plantations are located, as a rule, on base-unsaturated krasnozems and podzols where tea may be monocultured for decades. Observations show that the systematic and continuous application of fertilizers on tea plantations sharply affects the most important properties of the soil causing in particular a further increase in the base unsaturation of the soil and, as a consequence, an increase in all the indices of acidity.

Table 1 shows data based on an analysis of krasnozem from an experimental plot on a tea plantation in the seventh year of systematic application of ammonium sulfate with superphosphate. From these data it is apparent that an increase in acidity takes place at all the soil depths investigated (0 to 45 cm.). These indices are more sharply pronounced in the surface soil (0 to 15 cm.), which is most subject to the direct action of applied fertilizers. In this soil layer both the exchange acidity and the hydrolytic acidity are increased by more than three to four milliequivalents per 100 grams of soil. The pH of an aqueous suspension is correspondingly lowered to 4.1 and that of saline extracts to 3.6. As was to be expected, the quantity of adsorbed bases was correspondingly decreased.

Thus, where nitrogen and phosphorus are applied jointly in the forms of fertilizers mentioned, the exchange acidity and the hydrolytic acidity of the tea plantation soils which we investigated were increased after seven years by more than 70% over the controls. These data have been invariably confirmed in all subsequent investigations (4, 5, 6).

A comparison of the acidity in each modification of the experiment shows that the degree of acidification depends on the quantity of ammonium sulfate. The use of ammonium sulfate and superphosphate on krasnozems will, in a relatively short time, bring about conditions under which the normal development of many crops must be made more difficult or even impossible without radical chemical improvement of the soil. However, this is not observed with tea plants.

Before proceeding to the significance of this ecological factor for the tea plant, let us consider briefly the changes in other properties of the soils caused by continuous application of such fertilizers on tea plantations.

Changes in the Biology of the Soil as Related to the Use of Fertlizers. Having analyzed the soils from Academician V. R. Vil'yam's lysimeters, D. N. Karpechenko (9) showed that by the time the experiment was over, 3.54% humus had accumulated; it had been completely lacking in the starting sample. Studying the effect of continuous action of a fertilizer on the soil, F. K. Vorob'ev (1) established that a considerable amount of nitrogen and humus had accumulated. Later, F. K. Vorob'ev and P. M. Smirnov (2) confirmed the accumulation of organic matter and nitrogen with the continuous application of fertilizers on the peat-podzolic soil of the field experimental station of the Timiryazev Agricultural Academy. The accumulation of humus on the krasnozem of tea plantations was first observed by G. S. Godziashvili (oral communication); subsequent confirmation was provided by research by M. K. Daraseliya (8). The accumulation of humus on the soils of a tea plantation following the use of fertilizers may be easily observed, especially after drastic pruning of the tea bushes on experimental plots. The soils of the fertilized treatments of the experiments are usually distinguished by deeper brown coloration than the soils of the non-fertilized treatments.

We investigated the soils of experimental plots of tea plantations located in different climatic areas of the moist subtropical zone on which, beginning in 1932 and 1933, there had been annual applications of nitrogen in varying amounts in the form of ammonium sulfate with a constant amount of superphosphate (100 to 120 kilograms per hectare of P_2O_5). Determinations were made of the humus content, total

TABLE 1

Effect of fertilizers on the acidity of krasnozem (in milliequivalents per 100 grams of soil)

Treatment	Depth in cm.	Acidity		pH		Total adsorbed cations
		Exchangeable	Hydrolytic	H_2O	KCl	
Control .	0–15	4.6	6.4	4.9	4.2	5.4
	15–30	4.2	6.3	5.0	3.9	7.2
	30–45	4.3	6.0	5.2	4.0	7.3
N 150 kg./ha.	0–15	6.8	9.0	4.2	3.7	4.7
	15–30	6.5	9.6	4.7	3.6	4.3
	30–45	6.4	8.2	4.5	3.7	6.2
N 300 kg./ha.	0–15	7.7	10.9	4.1	3.6	3.9
	15–30	7.6	9.8	4.1	3.6	4.5
	30–45	7.1	9.2	4.4	3.6	4.8

TABLE 2

Effect of continuous application of fertilizers on soil fertility elements in tea plantations

Treatment	Total humus	Total nitrogen	Adsorption capacity (Bobko-Askinazi method)	Hygroscopic moisture, %	Field capacity, %
Experimental plot #73 Anaseuli					
w/o fertilizer	2.8	0.19	4.8	5.8	43.0
N 200 kg./ha.	4.2	0.30	11.2	6.0	53.0
N 300 kg./ha.	5.9	0.33	12.9	6.6	59.4
Experimental plot #42 Anaseuli					
w/o fertilizer	2.6	0.18	6.42	5.4	52.2
NK	3.7	0.36	7.7	—	—
NPK	5.2	0.38	8.8	7.2	55.8
Experimental plot #32 Anaseuli					
w/o fertilizer	2.8	0.23	5.6	4.9	42.7
NK	5.7	0.33	8.6	6.1	67.8
Experimental plot #21 Chakva					
w/o fertilizer	5.1	0.31	5.7	6.4	59.6
PK constant	6.7	0.32	10.5	7.4	64.0
N 150 kg./ha.	7.6	0.37	11.5	—	66.1
N 200 kg./ha.	7.6	0.40	11.1	7.2	66.7
N 250 kg./ha.	7.9	0.40	12.4	7.2	66.3
N 300 kg./ha.	—	0.41	13.4	—	66.6
Experimental plot #25 Zugdidi					
w/o fertilizer	2.9	0.12	5.1	2.5	44.0
PK constant	2.9	0.22	5.3	2.8	43.0
N 150 kg./ha.	3.6	0.27	6.1	3.4	50.0
N 300 kg./ha.	5.0	0.30	8.8	—	—

nitrogen and adsorption capacity, and certain indices of the water constants were studied (Table 2).

The data of Table 2 show a sharp increase in the humus content of all the soils fertilized for a prolonged period. On Anaseuli krasnozems the increase in humus content varied between 1 and 3% (as compared with the non-fertilized controls). Also, there was a considerable increase in the humus content following the systematic application of fertilizers to the podzolic soil of the Zugdidsk Branch of the All-Union Scientific Research Institute for Tea and Subtropical Crops (VNIIChiSK). This was in full agreement with the total nitrogen content. Thus, in the soils of plot No. 73 the nitrogen content went up from 0.19 in the non-fertilized treatment to 0.33% in the treatment where 300 kilograms per hectare of P + N had been applied. A similar increase in the content of this nutritive element is likewise observed in the soils of all the remaining plots.

The indices of the values of the cation exchange capacity are extremely important. As seen from the data of Table 2, the increase in capacity of fertilized soils amounts to 2 to 8 milliequivalents per 100 grams of soil.

As a result of continuous application of fertilizers, the moisture capacity of these soils also increases, in full accordance with the increase in their humus content. Thus, according to the data of Table 2, the moisture capacity of fertilized soils increased by 5 to 15% in comparison with the controls. This is important with respect to the improvement of water constants.

The use of NK, PK and NPK treatments in the investigated soils enabled us to suggest that the basic factor responsible for increasing the humus content and for other important changes is the joint application of nitrogen and phosphorus. This conclusion most clearly emerges from the data of the analysis of the podzolic soils (plot no. 25).

Reasons for Humus Accumulation on Tea Plantations. M. K. Daraseliya (8) and M. M. Kononova (11) consider the source of humus accumulation on tea plantations to be the decomposition products from the annual defoliation of the tea shrubs. Indeed, when fertilizers are used the total quantity of organic matter created by the tea plant is often increased four- or five-fold. A considerable portion of this material falls to the ground as fallen leaves and other dead organs of the tea shrub. However, a preliminary calculation shows that the amount of humus accumulated in the soil owing to the application of fertilizer considerably exceeds the quantity of organic matter that the soil receives from the tea shrubs. The accumulation, in addition, of a large quantity of organic nitrogen compounds shows that the nutritive elements applied in the form of fertilizer are widely involved in the biological cycle. It is known that organic residues of forest vegetation in the subtropical zone are in general very abundant and under natural conditions considerably exceed the amount of material which falls from the tea shrubs in one year. If the presence of humus in tropical and subtropical soils were directly dependent on the quantity of falling vegetable material, then a greater accumulation of it would be seen. However, it is known that the soils of this zone of the earth are not distinctively rich in humus. Thus Fageler (15) writes: "In the moist . . . semidarkness of the tropical and subtropical primeval forests, the conversion of organic matter . . . proceeds in such a manner that a twenty-centimeter layer which is really humified in the regular sense of the word, and a corresponding bed of litter, are a great rarity." Kittredge (10) exhibits data showing that in American forests, the amount of litter markedly decreases as one moves from north to south. Thus, in New Hampshire the litter amounts to 294.5 metric tons per hectare, whereas in Florida it does not exceed 4.2 metric tons per hectare.

In the subtropical zone, under the most favorable hydrothermal conditions, the process of weathering and decomposition of plant residues should be faster and deeper and should cause mineralization of the general mass of litter down to the final products of decomposition.

In the accumulation of humus on tea plantations, a process which is closely associated with the application of fertilizers to the soil, an active part is obviously taken by the micro-organisms living in the soil as well as by the plants. It may be considered proven that fertilizers stimulate the development of soil micro-organisms, which is undoubtedly reflected in the quantitative and qualitative composition of the organic matter. Ye. N. Mishustin (14) considers that under certain conditions, 0.15 to 0.30% of the soil mass may consist of the cells of micro-organisms. N. A. Krasil'nikov (12, 13) notes that the total mass of live micro-organisms in the surface soil of Central Asiatic sierozems reaches 7 metric tons per hectare. One of the most important peculiarities of the organic cycle in the soil, in Krasil'nikov's opinion, is that this unusually complex mass of living substance reproduces itself 8 to 12 times in the temperate zone of the country, while in the south, with a longer growing period, the quantity of reproduction may reach fifteen- to twenty-fold in a year. In his words, "in the surface layer of the soil, in the last analysis, tens of tons of living, extremely active material undergo conversion in one summer."

The general picture of the development of the bacterial population of krasnozem when fertilizers are applied is illustrated by our laboratory investigations (Fig. 1). In this experiment tubes of filter paper were introduced into test tubes, following which krasnozem without fertilizer was placed in one of the tubes, while the same soil to which NP had previously been added was placed in the other. The contents of the test tubes were moistened with distilled water and left to stand in the laboratory at room temperature under ordinary light. Photographs were taken on the tenth day after the beginning of the experiment. The second (right) half of the figure clearly shows the mass development of the micro-organisms living in the cellulose on the walls of the test tube. The difference between the NP and control treatments indicates the extremely positive effect of these nutritive elements on the development of micro-organisms.

Observations showed that under the combined action of NP fertilizer and the organic mass of tea leaves the direction of the biological processes in the soil undergoes an abrupt change. This is confirmed by the following laboratory experiment: Into each of five 150 cc flasks was placed 25 gm. of krasnozem from the experimental plot of the tea plantation. The krasnozem was sifted through a fine sieve and mixed with 0.5 gm. of old tea leaves, which had previously been dried and powdered. Ammonium sulfate and superphosphate were added to all the flasks (except the controls) and were placed in a constant-temperature oven at 28°C. Figure 2 illustrates the development of fungi in the different treatments of the experiment on the fifth day after it was begun.

The figure shows that the addition of only tea leaves to the soil or tea leaves plus nitrogen does not cause any visible change; however, when superphosphate is added together with the tea leaves the development of fungi becomes quite visible (flask 4). An even clearer picture

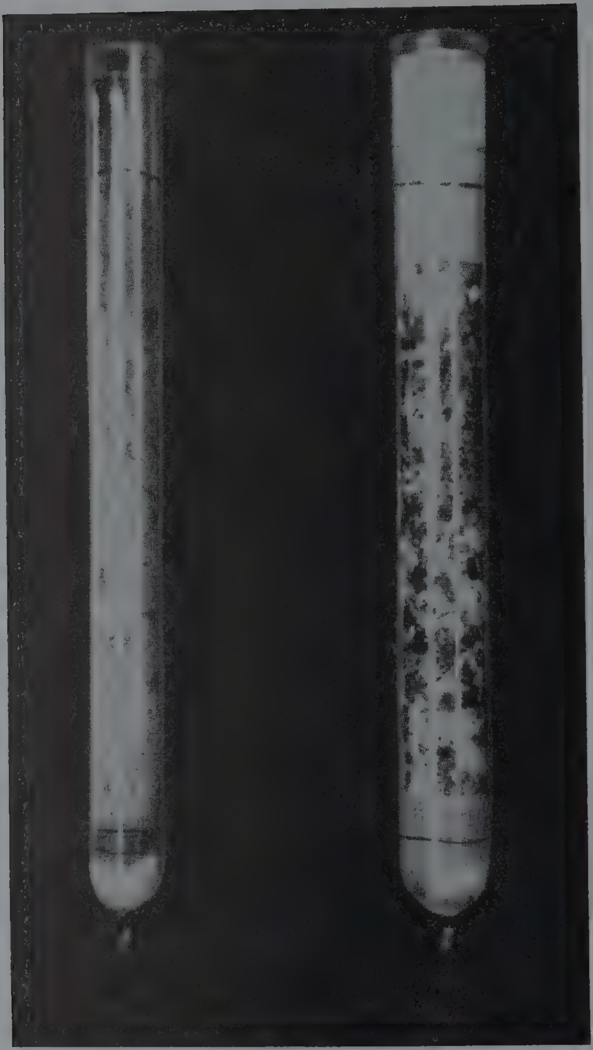

FIG. 1.—Development of microflora following application of fertilizers to krasnozem. Test tube 1—soil without fertilizer; test tube 2—soil + NP.

is provided by the treatment containing NP + tea leaves (flask 5).

To make a quantitative determination of the development of fungi in krasnozems with added fertilizers we used Butkevich's method on *Aspergillus niger* for determining the nutritive requirements of plants (16). For purposes of analysis samples of soils were taken from the treatment of the experiment in which no fertilizer had previously been used (soil no. 1), and from the treatment in which the soil had been fertilized for a long time with ammonium sulfate and was thus more acid (soil no. 2). NP, in the form of ammonium sulfate and superphosphate, was applied in the quantities required by Butkevich's method. Data are given below on the weight of the mycelia obtained on the eighth day of the experiment (in milligrams per flask).

Table 3 shows that the fungi develop most rapidly on sugar, furnished as energy-supplying

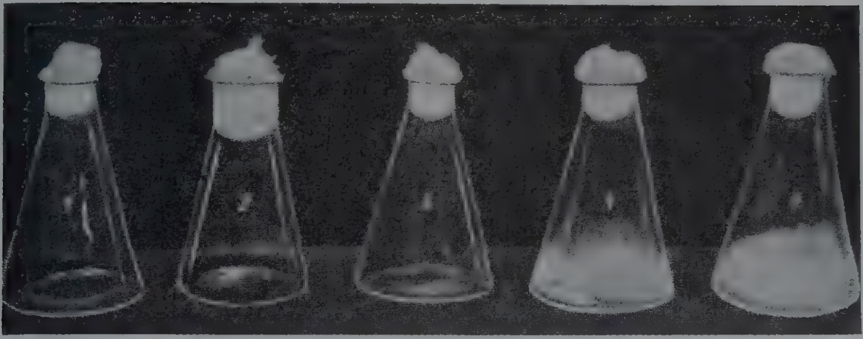

FIG. 2.—Development of fungi following joint application of tea leaves and fertilizer to krasnozem. Flask 1—soil + NP; flask 2—soil + tea leaf; flask 3—soil + tea leaf + N; flask 4—soil + tea leaf + P; flask 5—soil + tea leaf + NP.

material; however, in an acid medium and without sugar the positive effect of nitrogen and phosphorus fertilizers is noted. This shows that in subtropical acid soils, fertilizers stimulate the development of micro-organisms which use plant residues and humus as sources of energy. Given the necessary quantity of mineral nutritive elements, the development of these organisms may attain such proportions that considerable quantities of organic matter are formed. We have come to the conclusion that when fertilizers are applied to the subtropical soils of tea plantations, the formation of organic matter so predominates over its decomposition that a considerably greater accumulation of humus is assured than under the usual soil-forming conditions with natural vegetation.

TABLE 3

Effect of fertilizers on the development of fungi on krasnozem with different media reactions

Treatment	Soil No. 1	Soil No. 2
Control	0	0
Citric acid	16	40
Citric acid + sugar	43	50
Citric acid + NP	225	357
Citric acid + sugar + NP	970	1020

The Effect of Soil Acidification on the Productivity of Tea Plantations. It is known that at such acid pH's as are produced by the systematic application to krasnozems of physiologically acid fertilizers (3.6 to 4.0), most crops not only do not flourish, they die. A number of investigators have expressed this fear with respect to the tea crop. After studying the effect of continuous application of fertilizers on the properties of the soil, and productivity and chemical composition of tea leaves, M. N. Chernisheva (17) concluded that the system of fertilization adopted by tea plantations leads to a decrease in productivity and a deterioration of the soil. M. V. Gabinsoniya (3) notes the unfavorable effect of prolonged application of ammonium sulfate on the nitrogen nutrition of the tea shrub.

Nevertheless, our investigations and observations show that the acidity arising as a result of the continuous application of fertilizers and the changes in soil conditions caused by such application are, at least in the first two or three decades, favorably reflected in the productivity of the tea plantation, promoting its further growth. This regular pattern appears quite clearly in the analysis of the productivity of field experiments after prolonged application of fertilizers on tea plantations, particularly for the krasnozems of Anaseuli.

As seen from the data of Table 4 and Figure 3, the productivity of the non-fertilized control is stabilized at 800 to 1000 kilograms of tea leaves per hectare (disregarding the sharp decline between 1945 and 1949, which was common to the entire tea-raising industry and which was the result of wartime conditions). As for productivity of the plantations of the fertilized treatment of the experiment during the 20 years it was carried on, it is also characterized by a wide range of variations, chiefly due to the conditions already noted. However, a characteristic trait of the dynamics of productivity for this period is an undeviating, almost linear increase as com-

TABLE 4

Effect of continuous application of fertilizers on the dynamics of tea plantation productivity

Years	Treatment			
	Without fertilizers		NP	
	In kg./ha.	In %	In kg./ha.	In %
1935–1939	1146	100	1998	174
1940–1944	925	100	2537	274
1945–1949	379	100	1332	351
1950–1954	803	100	3425	426

TABLE 5

Soil acidity of highly productive tea plantations

Experimental plot	Depth in cm.	Humus, %	Exchange acidity, me./100 gm. of soil	pH of aqueous suspension	Productivity of plantation, kg./ha.
Chakvinskii State Farm	0–15	9.8	8.6	4.4	7000
	15–30	9.6	7.5	4.3	
Zvani, experimental plot #18	0–15	3.4	7.8	4.0	7600
	15–30	5.3	7.5	4.4	
Laiturskii State Tea Farm	0–15	9.4	6.4	4.4	2500
	15–30	4.1	9.1	4.3	
Plantation of K. Sarsanii	0–15	4.3	4.2	4.3	11000
	15–30	2.8	4.8	4.1	

pared to the non-fertilized control. For example, the average productivity of the fertilized treatment of a young plantation during its first five years was 174% of that for the non-fertilized treatment, whereas it amounted to 274% for the second five-year period. For the third and fourth five-year periods the yield was 351% and 426%, respectively, of the non-fertilized treatments.

In order to clarify this question better, we considered it necessary to trace the acidity of highly productive tea plantations operating under large scale conditions as well as the acidity of experimental plots, since, if this ecological factor exerts an unfavorable effect, the tea plant cannot develop a high capability for forming shoots. We carried out selective investigations of the soils of the most productive tea plantations of several state and republic collective farms. The data of Table 5 show that the soils of highly productive tea plantations are characterized by a pH of water suspensions of between 4.0 and 4.5.

Later, in order to study and draw conclusions from the experience of the leading tea plantations, similar examinations of the soils of highly productive tea plantations were carried out by a group of scientific workers from the VNIIChiSK [All-Union Scientific Research Institute for Tea and Subtropical Crops] under the direction of Professor M. K. Daraseliya (7). These investigations also showed that the soils of highly productive tea plantations were characterized, as a rule, by extremely acid pH's. It was found that the pH of water extracts of these soils lies between 4.0 and 4.5. Similar statements are found in the foreign literature. Thus, Russell (18) notes that the soils of the highly productive tea plantations of Uji, Japan, have a pH of 3.0 to 4.2 under the influence of systematic application of large quantities of fertilizers.

Thus, analyses and general conclusions based on data covering many years show that the tea shrub grows rapidly on the extremely acid soil caused by the continuous application of physiologically acid fertilizers. For the upper root zone of the soil (0 to 15 cm.) this acidity is usually determined by values of the salt extract pH's of 3.8 to 4.2.

The undeviating increase in productivity of the tea plantations systematically applying ammonium sulfate as the nitrogenous fertilizer responsible for this acidification shows that the tea plant not only tolerates an acid soil, but, at least for the first two or three decades of its development, even reacts favorably to an increase in its acidity. From this point of view ammonium sulfate should be considered as the fertilizer which not only supplies the plant with nitrogen, but also creates the most favorable soil conditions for the tea shrub. For this reason ammonium sulfate should be given the preference over all other kinds of nitrogen fertilizers by the tea-raising industry.

The reasons for this specific behavior by the tea plant with respect to its soil have been studied far too little, but they are evidently related to the biological peculiarities of this plant. Of primary importance is the fact that the tea plant is a shrub growing in the bottom story of the subtropical forest and, according to the literature, belonging to the mycotrophic woody shrubs, which are best adapted to soils with acid reactions. If we accept the existing statements regarding the beneficial effect of mycorrhizal fungi on their carriers—the cultivated

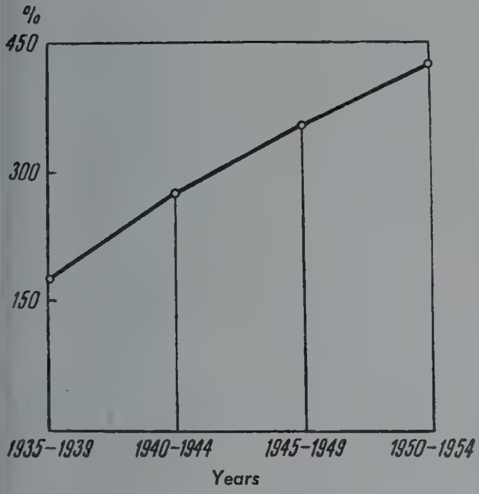

FIG. 3.—Dynamics of tea plantation productivity in relation to the continuous application of fertilizers and the changes with age of the tea plants (as % of non-fertilized control).

plants—it is not difficult to assume that conditions which favor the development of the fungi should also favorably affect the vital activities of the plant.

Conclusions

1. Investigation of the soils of experimental plots in different ecological zones of the moist subtropics shows that continuous applications of fertilizers on tea plantations causes the accumulation of humus and increases the total nitrogen content and cation-exchange capacity.

2. The increase in humus content of the soil and other qualitative and quantitative changes caused by continuous application of fertilizers are a result of the stimulating action of the fertilizers both on the tea plants and also on the soil microflora. The high content of tannins in the organs of the tea plant, especially in the fallen leaves, is a source of energy for the microorganisms and assures the predominant development of fungi in the surface soil.

3. Continuous application of physiologically acid fertilizers on tea plantations increases acidity of the soil to a pH of 3.8 to 4.5 and favorably affects the growth of the tea shrub.

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PREVENTING EROSION FROM HOLLOWS AND GULLIES BY TREE BELTS ALONG THEIR BROWS

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SHELTERBELTS located immediately above the sloping banks of a hydrographic system are usually designated as being rim ravines and rim hollows. Furthermore, these shelterbelts and others are collectively designated as rim shelterbelts. Rim shelterbelts are one of the most important elements of a network of protective plantings. Incidentally, their functions and potentialities for soil improvement have received little study. More mistakes have been made in choosing planting sites for them than in any other type of planting. Depending on the state of the normal erosion pattern (2), we divide rim shelterbelts into those along small gullies and those along large hollows. In order to simplify the terminology, the latter category also includes shelterbelts along large sodded hollows and small river valleys. Shelterbelts passing along all forms of accelerated erosion are classified as being rim gullies.

Rim shelterbelts carry out several functions simultaneously:

1. They absorb the runoff from the fields immediately adjoining the rims of waterways. This absorption is of substantial importance because having cut through the rim onto the steep slopes of the waterway, the currents of water from rainstorms and snowmelt can cause dangerous washouts. Even those large hollows where, for the moment, there are no washouts or scouring must not be considered as out of danger. Erosion may occur on them with a change in land use on the higher slopes, that is, an increase in the amount of thorough plowing with a crop rotation or the omission of perennial grass from it. An additional benefit from the absorption of the runoff by the tree belt consists in stopping the sediments and preventing silting on floodplains and in ponds.

2. When the surface runoff on the slope is absorbed, the rim shelterbelts convert it into subsurface runoff. However, since the steep slope of the larger hollow or the gully is always adjacent, the ground water seeps out or at least increases the moisture of the soil covering them because of the connection between the surface and the capillary fringe. This makes it possible to grow grass on the slope if it had been denuded, or to improve the stand of grass if there is one. The transformation of surface to subsurface runoff is undesirable only for creeping slopes. Then, the water should not be allowed to run off on the surface; instead, it should be kept high on the slope by plantings of trees which have a vigorous transpiration rate.

3. Rim shelterbelts protect the lower parts of cultivated slopes from erosion covering them with snowdrifts which melt later than the snow on the higher parts of the field; so that the snow-melt from the higher part, which is completely melted first, runs off through channels under the snow and does not have enough energy to cause washouts. This function of rim shelterbelts should not, however, be overestimated. N. I. Sus (7) states that rim shelterbelts noticeably affect the crop within 60 m. from the edge of the trees. G. A. Kharitov (8, 10) notes that slow snow thaw is not observed more than 100 m. from the trees.

4. In summer, the rim shelterbelts act as windbreaks and protect the adjacent fields from dry winds. But this action is distributed over a smaller distance than the action of a windbreak of the same height sited on a higher location because the rim shelterbelts are lower than the field.

Tree Belts Along Gullies. Usually small gullies form a winding net converging from the watersheds to the large gullies and ravines. To avoid washouts, small gullies should never be plowed across, but it is permissible and sometimes necessary to cross them with a tractor with its equipment raised. Sometimes three or four small gullies are encountered in a single trip of the tractor. If each gully were to have a shelterbelt, the field would be cut up into numerous small areas of the wrong shape and it would be extremely difficult to cultivate. For this reason not all small gullies are suitable for shelterbelts.

If there are no washouts along the entire course of the gully, it may be left in grass and measures are taken to improve the stand. But a gully in which pits and waterholes are washed out of the bottom must be planted with trees. The planting should consist of a silt filter occupying the bottom of the gully and a tree belt fringing it. In this case the crop rotation field must necessarily stop at the gully or the field must be divided into two tracts lying on different sides of it and cultivated separately. This does not actually result in shortening the length of the tractor run since the tractor is unable to pass over the washouts anyway.

When the slopes of some small gullies move back from the channel for a short distance and settle, their water-collecting capacity is small. In this case the shelterbelt parallel to the gully is placed on the level surface of the field having only a general slope toward the larger gully. The only importance of such shelterbelts is as a windbreak. They should be constructed only under conditions in which the small gully coincides with the boundary of the field or labor-team area, which must have a vertical belt to protect it from the wind anyway. In this case it is not necessary to construct a shelterbelt on both sides of the gully. If blizzards often occur in this locality the shelterbelt should be placed so that the gully lies to the weather side of it. In this case the main snowdrifts will not accumulate in the gully (which would intensify the force of the runoff and increase the danger of washouts), but instead will accumulate on the adjoining field. When a geometrically correct division of the field puts its end boundary at a short distance from the gully, the boundary should be moved right up to the gully. This makes it possible to plant trees on the gully without depriving the field of a small strip from the main area at the same time.

Gullies subject to washouts should be provided with shelterbelts on both sides; this will make possible climatic and biological permanence of the silt filter. Building shelterbelts on both sides of a gully subject to washouts is especially important when there is considerable catchment of water by its slopes. In this case the shelterbelts are located on the secondary slopes and extend toward the gully absorbing the runoff and thereby decreasing the loss of the flood water passing over them.

When a gully is being formed in a small ravine, A. S. Kozmenko (5) recommends extending shelterbelts along the ravine 15 to 20 m. above the top of the gully, while I. D. Braude (4) would increase this distance to 20 to 25 m. The latter recommendation has been adopted word for word in the instructions on methods of the Ministry of Agriculture of the USSR ("How to grow planted shelterbelts," 1955, p. 14). But the growth of the ravine in length along the bottom of the gully depends mostly on the current of water from the watershed which the gully drains, and shelterbelts of the negligible length proposed cannot slow this down to any material extent. According to Braude's calculations the channel may move up the indicated 20 to 25 m. in 5 to 10 years, but there are no grounds for hoping that it will stop there since its water supply from the head of the channel is practically undiminished.

Short sections of shelterbelts along gullies are useless for alluvial flooding. Their action would be more effective if they were set up as a part of the silt-filter complex. But the instructions on methods of the Ministry of Agriculture of the USSR do not recommend the planting of silt filters and suggest that the gully above the ravine be left in grass under all conditions. This advice means, in practice, abandonment of preventing the growth of channels in ravines. In order to deprive gullies of a substantial portion of their water supply, rim shelterbelts must be constructed along most of the length of the gully. Shelterbelts along the gullies acquire significance only when they border the undergrowth constituting the silt filter; the bushes will grow vigorously under the protection of the shelterbelt and form a tangle of roots which strongly prevents the head of the gully from moving. The distance by which the silt filter and its accompanying shelterbelt must be extended along the gully depends on the position of the gully in the system of crop rotation fields. Under conditions where the boundaries of the fields can be fitted to the gully and the areas on both sides of the gully can be cultivated separately, the shelterbelt along the gully and the silt filter should be extended as far back up as possible. If this cannot be done, the plantings in and along the gully should be extended only for a short distance from the head of the gully. In this case the interception of the flow to the head of the gully should be carried out by waterway.

Calculation of the width of the rim shelterbelts should be carried out in accordance with the topography of the location. When there is no seepage of water by the sides of the gully, the shelterbelt should be planned as a windbreak; but if the belt is located on a secondary slope where it intercepts the line of flow, it should be considered as intended for absorption of water and should be calculated on a basis which includes the degree and length of the secondary slope.

Tree Belts Along Hollows. In the instructions on methods of the Ministry of Agriculture of the USSR ("How to grow planted shelterbelts," 1955), the statement is made on p. 14: "Rim shelterbelts at the hollows and ravines are located along gullies, ravines, large hollows and dry valleys from one to five meters above the rim."

The rims of eroded hollows as a rule have, in outline, a meandering shape. The rims are also pierced by numerous ravines which in turn meander and branch. No matter how, in all their instructions, they prescribe that shelterbelts shall be squeezed in on the rims of hollows and ravines, the Agricultural Forestry Project has projected meandering shelterbelts going along hollows and transferring to a regular ravine, scrupulously duplicating all of the ravine's convolutions and bending around its multiple heads. On thousands of meandering shelterbelts planted in recent years along the rims of waterways the following phenomena can be observed:

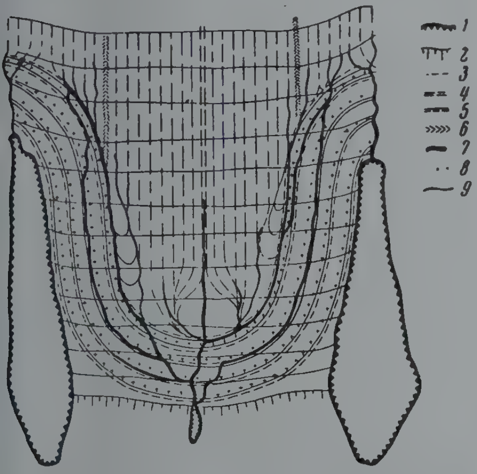

FIG. 1.—Catchment "sack" on a curved shelterbelt along the rim of a hollow with the usual direction of plowing (diagram): 1—Rims of ravines; 2—rim of a hollow; 3—plowed furrows; 4—deadfurrow; 5—drainage furrows; 6—accumulative ridge; 7—rippled washouts; 8—rows or clusters of seedlings; 9—contour lines.

1. Areas of shelterbelts going along ravines on the parts of slopes next to waterways are directed down slopes which are often as steep as 8° to 10°. Thus, the belts prove to be made up of steep rises alternating with bends which are no less steep. This makes it extremely difficult to prepare the soil and to maintain the trees after planting, and with tractor work there is great deterioration of the machines and waste of fuel; and the quality of the tillage goes down.

2. With tractor work along ravines with sliding or creeping slopes, elementary safety practices are infringed since the tractor driver is obliged to plow at a distance from the rim at which a heavy tractor train may cause a landslide.

3. With respect to preventing erosion, substantial importance can be attached to the circumstance that a rim shelterbelt with two wings which ajdoin a belt along a ravine, the crossing to which must be rounded off by the tractor driver, is converted into a seepage ditch (Fig. 1). At the lowest point of the ditch the runoff overflows the furrows, breaks through rows of young trees, and, with its current concentrated, is emptied into the hollow causing the formation of new washouts.

4. Areas of meandering shelterbelts located opposite the tops of ravines and intersecting water-conducting gullies take the greatest runoff loads. Here they are more necessary than all the rest, but it is just at this point that they are weakest. This is caused by the fact that a few meters from the head of the gully within the ravine, the ravine becomes deeper and has an uneven bottom. The plowshare does not dig into the soil or at best it only plows the surface layer. For this reason the seedlings or plantings of seedlings in these places most often do not succeed, or if they do succeed the trees do not survive.

5. Even those areas of shelterbelts extending along straight rims of hollows inevitably cut across small depressions in the surface. To the extent that the rim is located a total of one to five meters from the drainage furrow through which water flows, these depressions inevitably become channels for breakthroughs.

6. When the tractor makes a turn, the towed implement straightens out the track somewhat.

If the tractor-drawn maintenance of the space between rows passes from 30 to 50 cm. from the nests or rows of trees, the plows and cultivators inevitably undercut some of the young trees. To avoid this the tractor driver, working on strips consisting almost exclusively of loops and turns, only tills the middle of the interval between rows but even with this the young trees at the turns are still damaged. Because of incomplete plowing, meandering belts along the rims as a rule grow weeds more intensively than straight shelterbelts.

7. Constructing shelterbelts right up against the rims of hollows is also unsuitable because the soils here are usually washed out and in addition are dried out because of the draining action of the slope of the hollow and the evaporation from it. In the steppe zone they are often solonized (4). Forest growing conditions here are very poor and to grow trees, especially those placing demands on the soil such as oaks, is difficult.

Thus the location of rim shelterbelts at hollows, as recommended in some points of instructions on methods of the Ministry of Agriculture of the USSR, leads to intensification of erosion and creates great difficulties for the mechanized maintenance of shelterbelts and the growing of plantings.

In 1948–1952 the rim shelterbelts constructed on the hollows were almost exclusively of minimum width—20 meters. Instead of growing wide and possibly more compact shelterbelts on locations where they could absorb the runoff, they planted unusually drawn-out, wavering strings of belts leading aimlessly along the edges in the places where the runoff takes place almost exclusively along the hollows. The belts are not only incapable of combating this runoff, but they help to concentrate it even more. Unfortunately, in the latest recommendations of the Ministry of Agriculture of the USSR these shortcomings have not been fully corrected.

The sole argument in favor of such an inconvenient, ineffective and expensive system of rim shelterbelts is that with its use, the shelterbelts are squeezed as close as possible to the edge and so withdraw a minimum of arable land. The authors of the instructions were especially disturbed by the destiny of the tracts between ravines. They considered that if straight tree belts were laid out above the heads of the ravines the tillage of these areas ("sacks") cut off by the shelterbelt from the main body of land to be plowed could not be carried out jointly in one sweep, and for this reason would be made much more difficult. However in practice only the following two situations are seen:

1) The tracts between ravines have a soil cover which is so eroded and dissected by broad washes that its unsuitability for plowing makes little difference. On an enormous number of collective farms in the Orlovsk, Kursk, Belgorodsk, Voronezh and other regions before the use of shelterbelts these tracts had already been excluded from the arable land and were used in pasture rotation. Nor are they cultivated after the construction of shelterbelts.

2) The tracts between ravines have preserved their suitability for plowing. If the tillage is carried out according to the rules for preventing erosion, that is, across the slope, every tract between ravines is automatically separated to form an individual sweep. If the shelterbelts are then installed in a straight line separating the tract from the watershed area, practically nothing changes and there are no extra difficulties. The separation of tracts suitable for plowing is all the more natural since the depth and quality of these soils are different from those of the main body; they should be withdrawn and placed in a soil reclamation crop rotation and specialized farming practices should be used on them.

In both cases there is no justification for complicating the soil improvement work or for lowering the effectiveness of the belts along the rims of the waterways.

The authors of these instructions on methods, feeling that the decision which they suggest is unsatisfactory, attempt to soften it with some reservations. Thus they write: "On the slope of large hollows which are strongly dissected by washouts (at intervals of less than 100 m.) if the area is suitable for agricultural use only one protective belt of trees is planted, namely above the head of the washouts" (p. 15). It is regrettable that the exemption thus granted is extremely skimpy. Imagine that the distance between washouts is 150 m. In this case, according to the instructions on methods, a straight tree belt must not be installed; the belt must be drawn down in a loop along the ravines to the rim of the hollow. Here a minimum of 20 m. on each side will go to tree belts with 5 m. along the rim. If the plowing is carried out by even one of the small and relatively maneuverable KD-35 tractors with a four-furrow gang plow, the turn at each end of the sweep will take up 36 m. (6). Altogether, (20 + 5 + 36) × 2 = 122 m. On a straight sweep across the slope 28 m. is left. What kind of a modern tractor (except a shuttle type) can plow with such a sweep, or even with sweeps three times as long?

The recommendations in answer to the questions considered must be different: the interravine "sacks" located near the rims of hollows must be cut off by shelterbelts from the main body of land between hollows even if the distance between the ravines (or washes) along the contour line reaches several hundred meters. On tracts between ravines which are suitable for plowing and are less than 200 m. long tillage should be done only by shuttle tractors, tractor-mounted assemblies, or horsedrawn plows. It must be remembered that because we are removing the shelterbelt from the loops and extending it along a line at the heads of the gullies, the length of the tillage sweep will be increased by at least 50 m. at the expense of the belt itself and of the margins.

The rims of hollows are not always clearly defined. If the rim is not defined the tree belt along the hollow should be located at the lower border of the arable land, but on slopes of not more than 6° to 8°. The tracts below the shelterbelt which were formerly cultivated should not be tilled but should be used to grow grass.

The necessity for constructing shelterbelts along the edges of hollows and where they should be located is determined by the locality and by the stage and phase of development of the forms of accelerated erosion developing on the parent forms of normal erosion. The nature of the afforestation and of other anti-erosion measures depends in all cases on two factors: the need for measures to "treat" the affected slope and the possibility of economical use of the slope at a minimal rate harmless to the soil cover.

The basic cases of erosion on watershed slopes are pictured in Figure 2, which shows only washouts in the activephase—loss and transport. Washouts in the deposition phase do not require anti-erosion measures, since they will have already begun to consolidate themselves. As shown in the illustrations of forested (A) and sodded slopes (C) there is no direct need to construct shelterbelts along the hollows. This does not mean that they should not be constructed under any circumstances. Shelterbelts always make possible an improvement in the growth of grasses and woody undergrowth planted in the hollow. They improve the microclimate of the neighboring fields and provide brush and wood when they reach maturity.

If the conditions favoring runoff from the fields become worse—for example, if there is an increase in the proportion of crops requiring thorough plowing of the soil—a project for planting the rims of the waterways should be considered. If washes appear on the slope of the hollow, a series of fields of soil-protecting forage crop rotations should be undertaken (B and D) and tree strips should be planted along the rim of the hollow. Sometimes it is also necessary to plant trees on the slope of the hollow itself if, up to this time, it has only been under grass (D). If the rim of the hollow is straight and even, the shelterbelt should parallel it at a distance of three to five meters. If the rim has curves the shelterbelt should still be straight but the sectors cut off should remain under grass or have trees planted by hand. In this case the distance from the lower edge of the shelterbelt to the rim of the hollow should not be less than five meters. It is not necessary to set up a general limit for the length of straightened plots. Only the managers of collective farms and the directors of state farms, jointly with the workers at the Machine and Tractor Station, have the authority to decide in which cases it is or is not suitable to increase the area of arable land by several hectares or less by bending the shelterbelts and consequently complicating the tillage of the belts and also of the adjoining fields.

In case E the washouts below the rims have not yet cut through them. However, their forerunners, broad washes, are already so close together and so deep or the soil is washed to such an extent, that tillage of a belt along the rim has become impossible. This tract or strip which is not suitable for plowing should be left under grass or planted solidly with trees. The forest strip itself should be displaced to a higher location at the edge of the tilled tract. In this case the shelterbelt cannot be said to extend along the rim because it is located at a distance of several tens or even hundreds of meters from the rim.

In cases F and G the slopes above the rims of the ravine are dissected by a series of gullies which have advanced a considerable distance. But in type F the slope of the hollow between

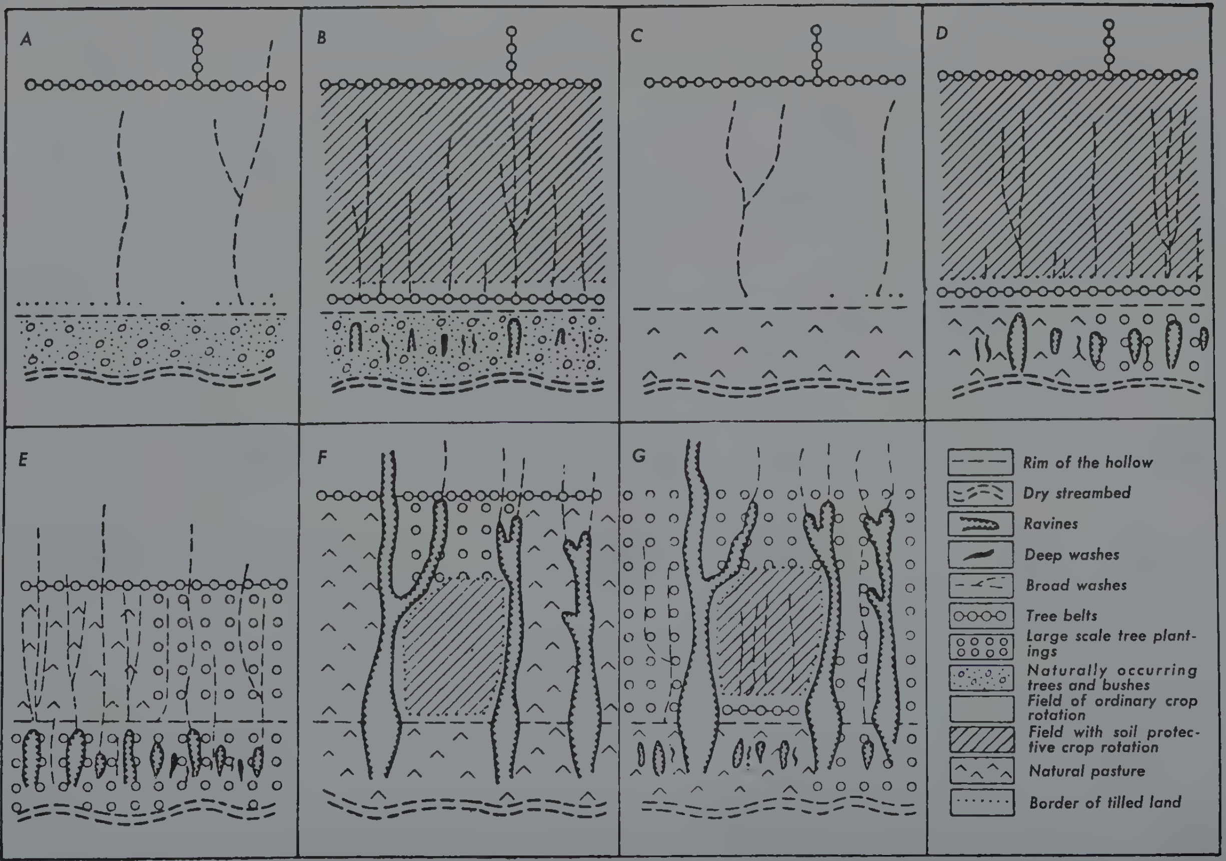
A
B
C
D
E
F
G
Rim of the hollow
Dry streambed
Ravines
Deep washes
Broad washes
Tree belts
Large scale tree plantings
Naturally occurring trees and bushes
Field of ordinary crop rotation
Field with soil protective crop rotation
Natural pasture
Border of tilled land

FIG. 2.—Different cases for planting trees on that part of a slope which is under the rim and near the hollow depending on the extent of erosion of the slope and also of the slope of the hollow (diagram). A. Slope of the hollow under trees; infrequent broad washes above the rim. B. Slope of the hollow under trees, but washing out continues on it nevertheless; a dense network of broad washes above the rim. C. Slope of the hollow under sod; infrequent broad washes above the rim. D. Slope of the hollow under sop, but washing out continues; a dense network of broad washes above the rim. E. Below the rim a dense network of ravines and deed washes, and above the rim a dense network of broad washes. F. Ravines above the rim and tillable tracts between them. G. Ravines

them is not eroded. This erosion takes place with the appearance of large gullies which do not occur because of excessive runoff from the entire surface of the field, but as a result of the formation in the fields of artificial rills—for example, deadfurrows, boundary ditches or roads. Under these conditions the use of the tracts between the gullies is determined solely by the size of the tracts. Where plowing appears profitable a small field of soil-protecting crop rotation should be separated. Where tillage is not indicated the tract should be sowed in grass or solid forest should be planted. With this anti-erosion shelterbelts should be set up above the heads of most of the ravines (although occasionally the longest ones may extend through the belts).

Case G is the most difficult. Here, in addition to the long gullies above the rims of the ravine, a whole network of gullies preceding by washing or by small hollows cuts down through the rims of the hollow threatening to convert the entire slope above the drainage net into worthless land. Under these conditions it is obligatory to plant trees on all the small areas between gullies and above the rim. Additional short shelterbelts should be planted along the hollow below them in the presence of larger tracts which have retained their arability.

If above the belt along the hollow there remain areas of useful grass, or if forage crop rotations are located there which include pasture crops, cattle access tracks should be left in the belt along the hollow.

When there are few or no deep washes [promoina] on the areas adjoining the hollow which can be plowed across (Fig. 2, A and B) (which should preferably be called "broad washes" to distinguish them from the currently used term "deep washes" which are not traversible by agricultural machinery) the authors of the instructions on methods recommend the use along hollows of belts 20 m. wide. But, as we previously said, the shelterbelt along the rim of the hollow is generally not necessary. If a fairly large washout exists, the instructions on methods recommend selecting the width of the shelterbelt as a function of the width of the higher-lying area enclosed between belts giving three limits:

Width of belt	Width of enclosed area
20–30 m.	400 m.
30–40 m.	400–600 m.
50 m.	600 m.

This principle of the direct relation between the width of the belt and the distance between belts is quite clear. However, the figures given here are without foundation and are completely unrelated to the steepness of the slope. Also conspicuous here is the lack of logic in the gradations. One of them (30 to 40 m.) is extended to the entire interval from 400 to 600 m., while another is related to a precise figure—600 m.—which has a negligible possibility of ever occurring. In practice this means a lowering of the maximum width of the shelterbelt to 40 m. instead of using the 50 m. established by law.

With respect to the construction of shelterbelts most investigators justifiably state that they should be dense with bushy undergrowth (5, 7), or they should at least be dense at the edges (9).

Tree Belts Along Ravines. This group includes tree belts planted on slopes above the rims and tops of ravines. The ravines below the rims are completely lodged in large hollows or valleys and the shelterbelts paralleling them (if it is expedient to plant them) should be considered a part of the total plantings of hollows or valleys which are not under consideration in this article.

The functions carried out by tree belts along the rims of ravines are no different from the general functions of belts along the rims of any waterways referred to at the beginning of this article. From this a general rule may be derived: Shelterbelts along ravines should be set up at the point from which the water supply of the ravine comes and should always be set up in the path of the current. There are two possibilities:

1) the ravine follows along the bottom of a large gully and receives the water caught by its sides. Under these conditions the creation of belts along the ravine is quite necessary since they can intercept a part of the runoff and stop or slow down washout; or

2) the ravine proceeds along an even slope and is supplied with water exclusively from its head. The water moves to the head of the gully via broad washes or small gullies which are located on a continuation of the ravine. In this case the tree belts along the ravine would not play a water-absorbing part and could not decrease the runoff through the ravine, thereby slowing down its further growth. The ravine must not be reclaimed by forestry methods and all efforts must

be directed toward retaining the water on the fields which are a part of the catchment basin and getting rid of the artificial obstructions which direct the water into channels.

A number of authors (1, 5, 8) place great hopes in the action of ravine-side shelterbelts in providing shade. They assert that shelterbelts along ravines are useful even when they do not stand in the path of the runoff or prevent the runoff from concentrating in the ravine. These belts act indirectly. By providing shade on the slope of the ravine they decrease evaporation and lower the soil temperature and so make possible the development of grassy vegetation which then strengthens the ravine. In these papers which propagandize the shade belts, cross sections of a ravine protected by tree belts are shown as an illustration. These profiles are usually not drawn to scale and do not observe the proportions or angles of slopes encountered in nature. Ravines are represented as being very narrow and with sheer slopes while the sun is lower than it has ever been in the summer daylight hours in our latitudes. Analyses of the actually possible steepness of the crumbling slopes (for it would be useless to try to reinforce slopes on which landslides were taking place), of the usual limits of the width and depth of ravines, and of the elevation of the sun in regions of protective forestry show that in the daylight hours even tall trees would not cast shade on the southern slopes where it is most needed. This is confirmed by observations. Experience shows that planting trees with tall trunks in the immediate vicinity of the steep slopes of a ravine is even somewhat dangerous because the swaying of the crowns in the wind leads to landslides from the rim. Moreover, when the trees are located in a single row the tap roots as they grow thicker widen the frost or drought cracks and also cause landslides (11). In this connection, the advocates of shade belts recommend placing the first two or three rows of the tree belt on the rim side with bushes having root suckers which resist wind and reinforce the slope by their numerous interwoven roots. In case of a landslide, these bushes adapt well in their new location. However, these changes have not been widely used. The low height of the bushes is by no means a guarantee against landslides. The very best shelterbelts along ravines are powerless to prevent undercutting of the slopes by small streams flowing in the bottoms of the ravines. At the same time the replacement of trees by bushes has finally settled the question of non-shading belts along ravines.

Thus, the danger of erosion and washouts on tilled slopes adjoining shelterbelts which parallel ravines having a steep downgrade is very great because of accumulating snowdrifts at the edges, but the shading action of the belts (for which this danger was artificially created) is, in most cases, imaginary. If we find shading action of shelterbelts along ravines undesirable, there still remains their beneficial windbreak action on neighboring fields and the increased moisture of the slopes through the accumulation of snow. These useful actions are desirable but we should not run the risk of provoking new washouts because of them. They are useful only whenever the danger of washouts is absent. Windbreaks should be planted along ravines only when the slope of their brows is shallow.

The question of the distance between rim shelterbelts along ravines is of great importance. In order to select the correct distance from the rim to the shelterbelt, consideration must be given to the phase of development and the process of formation of the slopes of the ravine. The sliding walls of a ravine should never be reinforced other than by stone masonry. Frost and physical weathering, washouts and wind erosion, and the action of roots and excavating machines will of necessity cause the walls to slide and recede until they assume an angle of natural inclination. No vegetation growing higher than the rim can stop this process and nothing should be planted or grown on sheer walls. The normal evolution of the sliding bank of a ravine consists in its moving back parallel to itself from the axis of the ravine. When it has moved back so far that temporary streams begin to undercut it, it turns into a crumbling slope with a pile of rock waste formed first at the foot and growing upward. However, the formation of rock waste can only be stable when the ravine goes into the phase of deposition and deep erosion stops, and when the rock waste is no longer washed down and begins to be reinforced by vegetation. This shows once again that measures to secure ravines can be considered only as measures to promote the absorption of runoff on the catchment area, while the work of planting trees and grass on the slopes of the ravines themselves is a subsequent

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phase—the phase in which the already secured ravines are converted into useful land. These phases may partially overlap at times.

If the belt along the ravine cannot stop the growth of the ravine in width and prevent its slopes from settling to a natural angle, then after the flattening process is all over there is no need to secure it—the ravine secures itself. At this time it is routine to cover it with a carpet of vegetation and to provide a favorable microclimate and water conditions that will enable the carpet to grow. This function may be carried out by windbreaks which accumulate snow near the ravine and decrease transpiration. These windbreaks should be fairly high by the time the slopes of the ravine have settled and for this reason they should be planted well beforehand. The windbreaks should not be planted right on the sheer rim existing at the time, but at such a distance back from it that it will be on the rim when the slope has finally attained an angle of 30° to 35° (Fig. 3). This distance is not hard to figure.

Shelterbelts along gullies which are important

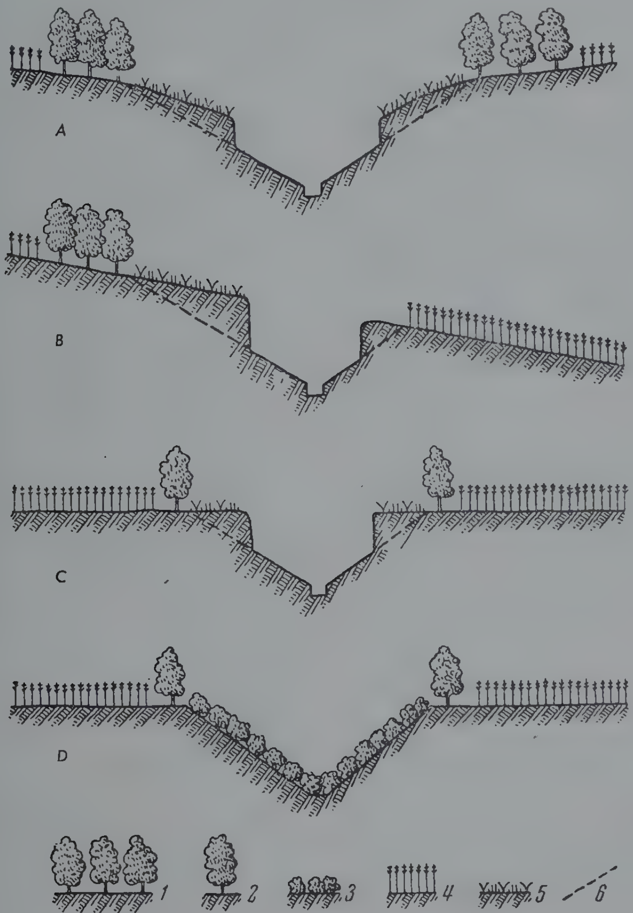

FIG. 3.—Various conditions for locating tree belts along ravines. A—Ravine with water catchment from both sides, going along the bottom of a small gully. B—Ravine with catchment from one side proceeding diagonally to the line of maximum slope of a road, edge of a field, and so forth. C—Ravine with the remains of slopes which have slid over rock waste; no water catchment from the sides. D—Stabilized ravine without catchment from the sides: 1—anti-erosion tree belt; 2—windbreak; 3—plantings of bushes; 4—plowland; 5—areas in grass; 6—line along which slopes settle.

in preventing erosion go in a direction which is always necessarily oblique to the contour line. To insure their water-absorbing activity, their borders must be carefully tended and provided with structures to dissipate runoff. However, with any structures directing the runoff into the shelterbelt the greater the angle at which the runoff approaches the belt, the better. The angle can be increased by increasing the distance between two belts as they approach the hollow.

It is very important in the transition from the ravine shelterbelt to the belt along the hollow (where the slope makes it possible to lead the belt as far as the hollow) not to make an even bend, but to lead the straight ravineside shelterbelt directly to the upper edge of the hollow shelterbelt. This not only makes it easier to till both shelterbelts and to give each belt a different width and construction, but it also assures absorption by the hollow shelterbelt of runoff from that along the ravine if the latter belt should prove to be unable to absorb the runoff itself. The belt along the ravine should not be made continuous with that along the hollow; a sodded space should be left through which a tractor and equipment can work. In some cases this may also be used for a cattle crossing.

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Methods

USE OF FLUORESCENCE MICROSCOPY IN SOIL MICROBIOLOGY

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The number of micro-organisms in the soil is a basic prerequisite for evaluating its biological condition. There are two general methods of establishing this number: one involves cultivation on nutrient media, the other direct determination. The first gives an idea of both the species composition and the physiological groups of the soil bacteria at the same time. However, since the figures thus obtained are much lower than those representing the actual content of the micro-organisms, we prefer the other or direct determination method as being more accurate.

A method of direct determination of the number of bacteria in the soil was worked out by S. N. Vinogradskii (1). It has undergone a number of modifications, including changes in the technique of preparing bacterial suspensions (Germanov [2]) and replacement of the microscope slide by a counting chamber (Jones and Mollison [6]). Numerous modifications have dealt with staining the preparation. However, the basic principles of the method have been preserved. Vinogradskii's method made our ideas of the number of bacteria in the soil considerably more precise, although not permitting us to distinguish between live bacteria and dead ones. A number of investigators have tried to remedy this shortcoming, but the only one to succeed was Strugger (7, 8), using fluorescence microscopy with acridine orange as the fluorochrome.

Having studied the question of dyeing various subjects with a fluorochrome, Strugger established that, unlike other dyes, acridine orange fluoresces in different ways depending on the concentration; a subject which absorbed only a small quantity of this dye would fluoresce with a bright green color while one which absorbed a large amount of the dye would fluoresce a rich red. Strugger used this discovery for vital staining, based on the generally known fact that live tissues take up a considerably smaller quantity of the dye than do dead tissues. The relationship of fluorescence of acridine orange to its concentration as well as the differences between staining live and dead subjects also enabled him to distinguish live bacteria from dead bacteria in microscopic preparations. He quickly realized the particular usefulness of this discovery for soil microbiology and worked out a method for staining soil suspensions with acridine orange (Strugger and Rouschal [8]). In spite of its extreme simplicity, this method was not disseminated. It was not until more than ten years after his discovery that Strugger's institute began to publish the first papers devoted to the more or less wide use of fluorescence microscopy in the microbiology of the soil (3, 4, 5). After becoming acquainted with this work, we also began to use the fluorescence method and soon succeeded in getting the same good results as the German scientists.

The Strugger method of staining soil suspensions is extremely simple. We have made only minor changes in it. Fresh, one-gram soil samples are weighed out into five test tubes; the samples were previously ground in a mortar and sieved through a two-millimeter mesh. The test tubes are then filled with 10-cc of acridine orange solution in decreasing concentration from

1:1,000 to 1:5,000. The test tubes are shaken vigorously for five minutes and the liquid allowed to stand. For further work we choose a test tube where the solution above the precipitate contains a slight excess of the stain, that is in which the liquid fluoresces a weak yellow-green color. This method is necessary because the organic part of the soil also absorbs the stain and the degree of absorption must be tested empirically. If the work involves samples of uniform soils the suitable dye concentration may be first empirically established and then used for all subsequent determinations.

Suspensions containing a ratio of soil to liquid of 1:10 are not suitable for microscopy; we add to the test tube selected for the experiment enough water to fill it to about three-quarters of is capacity, shake it, and after the solution settles we draw off the liquid above the precipitate with a graduated pipette into a volumetric flask. Water is added again and the operation repeated until the water in the test tube remains clear after shaking. The liquid is then poured into the volumetric flask up to the mark and we proceed to prepare the microscope slide. To place a given amount of suspension on the slide we use a hematologic pipette which enables us precisely to measure out 10 cubic millimeters of solution. The drop is immediately covered with a 20 x 20 mm. cover glass and vaseline is applied at the edges to prevent it from drying out. A Zeiss fluoroescence microscope is used having as a source of light an arc lamp with two opposing carbons at right angles to each other, one being impregnated with mercury. The light is passed through a blue filter. The optical system consists of an oil immersion lens (× 100) and a 10-power ocular. Observations are made at maximum diaphragm opening. To facilitate observation a square grid, with the length of each side corresponding to 200 microns on the slide, is placed in the ocular. Fifty fields are examined each time; they are distributed as far as possible over the entire area of the cover glass.

The observations are made in complete darkness. The bacteria, which fluoresce with a bright green color, are easily distinguished against the dark background of the preparation or the red reflection of the humidified soil particles. We count the number of separate bacteria and those in small colonies wherever possible. We relate larger colonies to the number of zoogloea and count one zoogloea as 10 bacteria. In this we differ from Burrichter, who counts one zoogloea as 50 bacteria. However, in all probability he counted the individual bacteria in larger colonies. We make not less than two slides from each test tube and immediately compare the count. If the difference is greater than 10%, we make a third slide. Two determinations are made for each soil sample, so that never less than four slides are made. A dilution is used whereby one field contains 1×10^{-9} of the original sample. After finishing the determination we recalculate on the basis of dry weight and increase the result by one third to compensate for the error caused by not counting the bacteria on the undersides of the soil particles.

We checked the correctness of our counts by a statistical evaluation of the results. When based on the number of colonies in one field, the distribution turned out to correspond to Poisson's theorem. Thus we feel that the glass slide is as suitable for counting as the counting chamber recommended by Strugger, for which the Poisson distribution was established by Jones and Mollison (6). Furthermore, we checked the correctness of individual determinations on soil samples taken from under the same types of vegetation and proved that the above method is fully suitable for the quantitative determination of soil bacteria. The errors to which it is subject are no greater than those of other methods.

The direct method of determining bacterial counts by fluorescence microscopy can be used to supplement any soil microbiological analyses. This method, however, is particularly advantageous whenever it is urgent to make rough comparative determinations of soil compositions in a small area having a uniform climate.

To illustrate: not long ago we used this direct method in estimating the biological composition of forest soil under different types of vegetation—an 80-year-old spruce stand, a 30-year-old birch stand, and a grass cover (*Calamagrostis epigeos, Deschampsia caespitosa*).

The birch and grass grew on a place where, 30 years before, a part of the spruce forest had been cut. We proposed to determine whether the birch improved the biological condition of the soil which had formerly been under spruce. This involved a comparison of the effect of solid birch cover and that which had been thinned out (clearings 5 and 15 meters in diameter). The

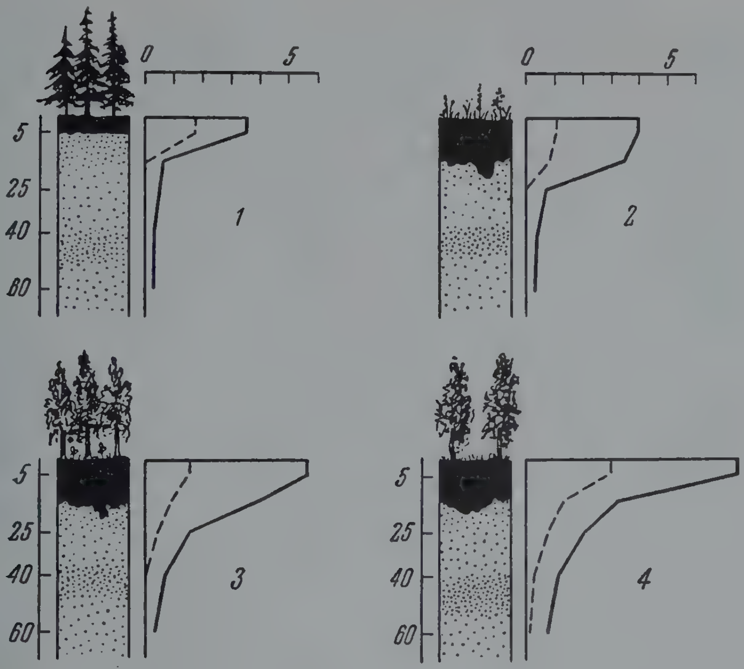

Fig. 1.—Number of micro-organisms in the soils under different vegetation. 1—Spruce forest (80-year-old pure stand); 2—Grassy cover; 3—Birch stand; 4—Birch stand with small clearing.

investigations took place at the beginning of May. Soil samples were taken from depths of 5, 15, 25, 40, and 60 centimeters and were processed within 24 hours. The results are shown in Figure 1, where the number of bacteria in billions per gram of dry soil is shown on the X-axis (the dotted line shows the number of bacteria in zoogloea); the Y-axis shows the depth in centimeters along the soil profile. The nitrification rate was determined at the same time as the bacteria count; these results are also shown in Table 1.

The study showed that the number of bacteria in soils under different types of vegetation is not the same. The soil which had been under birch for the last 30 years had a greater population of microorganisms than those under grass or spruce. The favorable effect of the birch was shown in the increased number of bacteria at all depths along the profile. The grassy cover somewhat intensified the biogenicity of the deeper portions of the soil. We were thus able to confirm the favorable effect of birch on the biogenicity of the soil. The correctness of our results is confirmed by the nitrification rate, which was greater under all tracts of the birch stand than under the other types of vegetation.

A second example also deals with the effect of vegetation on the biological composition of the soil. It is taken from the data of a broad investigation of the geobotanical conditions of limestone cliffs in the Karlstein region. The soil investigated was a shallow rendzina. The object was to give a microbiological characterization

Table 1

Nitrification rate in the upper layers of the soil under different types of vegetation

Plant cover	Mg. of nitrate N per kg. of soil after 14-day incubation
Spruce forest (80-year-old pure stand)	2
Grassy cover (*Calamagrostis, Deschampsia*)	8
Birch stand (solid cover)	16
Birch stand with wide clearings	23
Birch stand with small clearings	29

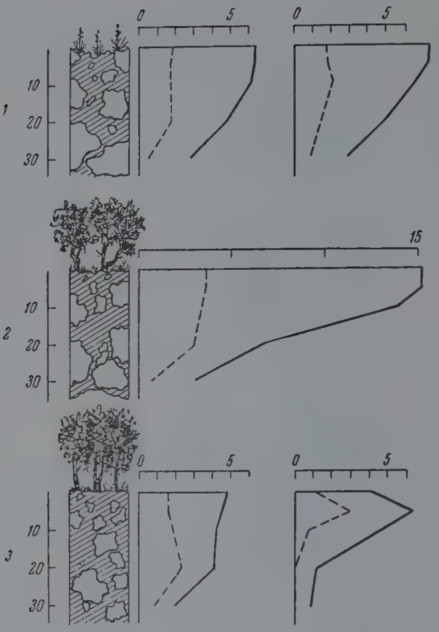

FIG. 2.—Effect of different plant communities on the number of micro-organisms in the soil. 1—*Lathyrus versicolor—Festuca glauca;* 2—*Quercetum lanuginosae;* 3—*Quercetum carpinetum.*

of the soils of three plant communities on a cliff terrace about 200 meters long. As determined by Klik these communities were (a) *Lathyrus versicolor—Festuca grauca,* (b) *Quercetum lanuginosea,* and (c) *Quercetum carpinetum.* The first of these represents the initial stage; the second, the stage of full development; and the third, the transition to cultivated forest. We were interested in the effect of *Quercetum lanuginosae,* the stage of most complete development for this region, on the population of soil micro-organisms. After orienting analyses in the middle of April we carried out the main determinations at the beginning of May. Five soil samples, taken by a probe, were analyzed from each community. Figure 2 shows the indexes which are the arithmetical averages of the amounts obtained. The X-axis shows the number of bacteria per gram of dry soil; the Y-axis shows the depth of the soil profile in centimeters.

The results show clearly that the soil under *Quercus lanuginosa* contains a larger number of micro-organisms than the soils under the other two communities. Furthermore, the large amounts of bacteria we found show how incomplete our knowledge has been of their actual number in the soil. Judging from the literature, the greatest number previously found has been about 10 billion per gram of soil. The figures we obtained are half again as large. Our data correspond with those of Burrichter (4, 5) who referred to the high content of bacteria in rendzinas.

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ZONAL DISTRIBUTION OF CALCITE IN SOILS AND SUBSTRATA OF THE AMU-DAR'YA DELTA

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KNOWLEDGE of the migration paths of the elements is of great importance in the study of processes taking place in the soil. Rivers play an enormous part in the migration of elements. The well-known formula of A. I. Voyeikov (2), "rivers are the product of the climate," includes not only the hydrologic idea, but to an even greater degree the effect of the climate on the geochemical processes associated with the activity of rivers. Developing this idea, G. A. Maksimovich (3) refers to the geographic zonality of the hydrochemical conditions in rivers. He distinguishes five basic zones: the zone of tropical rivers with a preponderance of silicate and carbonate waters; two zones in the southern and northern hemispheres in which sulfate and chloride waters predominate in the dry steppes; and two zones of the extreme north and south in which carbonate waters predominate.

Considering carbonate conditions in rivers, N. M. Strakhov (6) directs attention to the geochemical differentiation of carbonates which is determined by the effect on the hydrochemical conditions of rivers of their presence in one or another of the climatic zones. In the great river systems cutting across certain climatic zones Strakhov notes a definite tendency for rivers to become either more or less saturated with carbonate salts as they pass from the upper reaches to the mouth. Rivers flowing south gradually become saturated with carbonates; but in rivers flowing north, the degree of saturation with carbonates decreases passing downstream. In the first case the carbonates are easily deposited at the mouth of the river (for example, the Volga), while in the second case they are carried out to sea in dissolved form (for example, the northern rivers of Siberia).

However, the hydrochemical metamorphosis of river water from the source to the mouth does not always take place in a single direction, especially where the qualitative composition of the elements does not remain constant. The failure of the qualitative composition of the elements migrating with the river water to remain constant disturbs the geochemical zonality associated with the climate. Great importance is acquired by other factors which depend on the local terrain where one section or another of the river flows. This develops especially clearly with rivers passing through deserts and is easily seen particularly in the example of the Amu-Dar'ya. Here many elements are not carried all the way to their lowest level. Their differentiation occurs while moving along the river itself. A major role in this respect is played by the nature of the exchange of water between the surface water of the river and the ground water of the riverbed deposits.

The direction of flow of the ground water in the alluvial riverbed deposits does not always coincide everywhere with the direction of flow of the river. Agreement of the surface and ground water flow in time and space is confirmed only in the mountainous part. On the plains, in the region of transit flow and especially on the delta plain only the ground water flow of the riverbed deposits changes its direction with the seasons. Furthermore, along the entire course of the plains portion of the river this current is not a continuous entity; it is interrupted and narrowed down at places where the bedrock crops out. For example, the Amu-Dar'ya has such a narrows in the region of the Tyuya-Muyun gorge, where a weakly filtering mesozoic rock has developed, and also in the region of Sultan-Uiz-Dag where practically impermeable paleozoic rock has developed. As a result of these restrictions of the flow of ground water under the river the stream flow is supplied in the lower course not by the ground water of the area around the streambed (which actually lies farther upstream) but by the flood waters of the Amu-Dar'ya. Along isolated portions the Amu-Dar'ya gives off its water at the flood, only to have it returned in midsummer. As a result of such a seasonal exchange of water there occurs an independent salt exchange and a geochemical isolation of these tracts which is independent of the climatic zonality.

The exchange of the surface water of the Amu-Dar'ya with the ground water of the alluvial de-

TABLE 1

Chemical analysis of Amu-Dar'ya water according to data from the laboratory of the 31st expedition of the "Hydroproject"

Date sample taken	Cations and anions in mg./l.							Remarks
	Ca	Mg	Na + K	HCO_3	SO_4	Cl	Total ions	
July 3, 1952	61.2	27.4	16.8	133.2	115.2	51.6	405.4	
Aug. 4, 1952	51.3	15.8	9.9	94.6	79.0	39.1	289.7	Flood
Oct. 15, 1952	64.1	11.2	52.4	112.9	124.2	69.4	434.2	
Jan. 14, 1953	84.5	28.2	67.4	148.3	166.2	126.9	621.5	
Mar. 16, 1953	83.3	24.9	80.3	128.0	195.9	124.8	637.2	Low Water
May 9, 1953	72.0	20.7	57.0	122.0	136.6	103.5	511.8	

TABLE 2

Hypothetical salt content of Amu-Dar'ya water at flood and at low level (near Nukus)

Date sample taken,	Content of salts in %					
	NaCl	$MgCl_2$	$MgSO_4$	$CaSO_4$	$Ca(HCO_3)_2$	Total
At summer flood, Aug. 4, 1952	10	16	14	24	36	100
At winter low, Mar. 16, 1953	36	—	22	20	22	100

posits of the streambed and of the soils is reflected in a seasonal change in the salts of the river water. With a general increase in the concentration of salt in the water in a downstream direction the seasonal variations in their concentrations also increase. For example, in the summer months the concentration of salts in the Amu-Dar'ya in the Nukus region does not exceed 300 milligrams per liter, but in the winter it increases to 600 to 700. Table 1 shows analyses of samples of Amu-Dar'ya water taken in the area of the main installation of the Lenin Canal near Nukus. Average figures from the analyses of 101 samples taken from various parts of the active current of the river have values close to those given in this table.

The amount of decrease in the concentration of the salts in summer and the amount of increase in winter characterizes the volume of the summer accumulation of water in the deposits of the streambed during the flood and the volume of the winter return of the more mineralized ground water at the low midsummer levels.

Considering the water balance of the Amu-Dar'ya in the area between the towns of Kerki and Nukus, A. K. Proskuryakov (5), on the basis of purely hydrometric data, states that the accumulation of water in the streambed deposits during the flood and subsequent wearing down of the water prism has quite a material effect on the redistribution of the streamflow of the Amu-Dar'ya within its transit portion. In the months of the greatest rate of level rise—April and May—along the entire length of the tract from Kerki to Nukus, the supply of ground water at the expense of the Amu-Dar'ya reaches 170 cubic meters per second. In the months of the greatest rate of level fall—August and September—the river receives more than 200 cubic meters per second from the ground water.

That the underground flow in the alluvial deposits of the streambed has a definite direction, depending on the season, is shown not only by changes in the salt concentration and by the hydrometric data, but also by the seasonal fluctuations of the level in the piezometric pores in the deposits near the streambed. For example, in the region of the town of Kipchak on the left bank these fluctuations in the sandy-clay alluvial substrata spread from the river deep into the bank for a distance of up to a kilometer. Beyond the limits of this distance there is noted a constant flow in one direction from the river. Different conditions of the flow predetermine different conditions of the migration and accumulation of elements. Table 1 shows that the Amu-Dar'ya water reaching the alluvial substrata during the flood and at low stage of water (mixed with ground water being returned to the river) are considerably different in their chemical characteristics. The relation of the separate components in the summer and winter water, recalculated on a hypothetical basis, is shown in Table 2.

From this table it is seen that the summer flood water is characterized by a large quantity of calcium bicarbonate (up to 36%) and by a small quantity of sodium chloride (up to 10%). A content of up to 16% of magnesium chloride is characteristic of the summer water. In the summer water there is more calcium sulfate and less magnesium sulfate, while winter water has more magnesium sulfate and less calcium sulfate. In estimating the balance of the seasonal exchange of elements between the alluvial deposits and the water it is seen (from Table 2) that Amu-Dar'ya water, while being filtered through the streambed deposits, loses calcium, magnesium and bicarbonate ions and acquires a higher concentration of Na^+, Cl^- and $SO_4^{=}$ ions. The alluvial substrata and the soils near the streambed take on calcium carbonate and lose sodium chloride and sodium sulfate and, in addition, in the adsorption complex they take on calcium and magnesium ions and lose sodium ions. As a result of this exchange, an accumulation of calcium and magnesium takes place in the soils and substrata.

A comparison of the results of large-scale analyses of aqueous and hydrochloric acid extracts of the alluvial sands (of the same texture) taken from the top of the delta and from its low-lying part shows that the calcium content recovered from the water extract remains almost unchanged and does not exceed 0.2 to 0.5 grams per kilogram of dry sand. The calcium content recovered from the hydrochloric acid extract gives a different picture. In samples of sands taken from the top of the delta, the calcium content is not more than 30 grams per kilogram of dry material; in samples from the low-lying part of the delta the calcium content recovered from the hydrochloric acid extract is almost three times as large. The quantity of bound carbonic acid is correspondingly increased. It is fully obvious that the accumulation in alluvial deposits of calcium in the form of calcite begins the moment the deposits are formed.

The accumulation of calcite in alluvial substrata is especially noticeable in low-lying parts where inundations at flood time attack the widest areas. This is seen from the analyses of the content of salts in the alluvial substrata of the various parts of the delta. With samples of uniform texture taken from the top of the delta and from its low-lying part, the greatest calcite content is found in the latter. This pattern is represented graphically in the figure; it shows the results of 60 analyses of sand with particles having a diameter of 0.085 to 0.090 mm., and the results of 62 analyses of sandy loams containing 80 to 90% of particles between 0.05 and 0.005 mm. As shown by Figure 1, in the peripheral portion of the delta within its lower hundred kilometers in texturally uniform deposits, the calcite content of the sands reaches 200 grams per kilogram of dry material, while that of the sandy loam reaches 300. At the same time, at the top of the delta in similar deposits the amount of calcite is correspondingly almost twice as small.

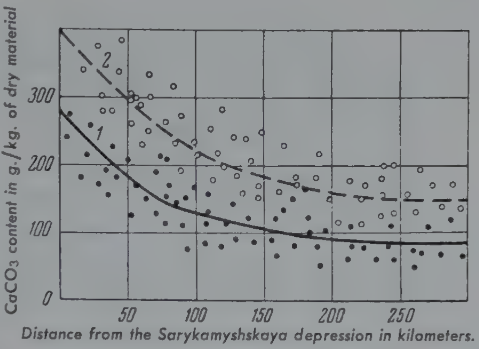

FIG. 1.—Content of $CaCO_3$ in the alluvial deposits with uniform texture as affected by their location in the Sarykamyshskaya delta of the Amu-Dar'ya. 1—Sand. 2—Sandy loam.

The examples cited above illustrate the development in the Amu-Dar'ya delta of a definite soil-geochemical zonality. Separate tracts of the delta are characterized by different conditions of migration and exchange of elements. In outline the zone of exchange is divided into two belts. The upper belt, located within the transit section of the river, is characterized by the presence of tracts with seasonal changes of direction of the underground current. Such tracts are located within the limits of a comparatively narrow belt of river deposits near the banks. The second belt of the exchange zone is located in the lower reaches of the river where the present delta is formed. This belt is characterized not only by seasonal changes in the direction of the underground flow, but also by occasional floods attacking large areas of the alluvial plain. Thus, at this point, in addition to the seasonal exchange of elements, a process of exchange and accumulation of them takes place as a result of repeated yearly changes in the direction of the surface and underground flow. The soils and substrata in this belt are characterized by the greatest calcite content.

The basic conclusion arising from the zonal distribution of calcite in the Amu-Dar'ya delta is that different tracts of the delta are characterized by different conditions of geochemical exchange. This is of the greatest practical importance. The increase in the calcite content of the alluvial deposits in the low-lying parts of the delta are favorable soil improvement factors and may be used in planning and reclaiming new argicultural areas.

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THE IMPORTANCE OF EXCHANGEABLE CATIONS IN THE ADSORPTION OF $SO_4^=$ BY SOILS

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MANY investigators have established that the quantity of phosphoric acid anions adsorbed is closely dependent on the composition of exchangeable cations in the adsorbing complex of the soil (1, 3, 4, 5 and others).

It must be assumed that soils which are saturated with different cations will not react the same with sulfuric acid or its salts.

Because this question, which is of great practical importance, has not been studied at all in the past, we carried out a corresponding investigation. For the experiment we took peat-podzolic soil from the area of the Ivanovskaya Experiment Station, leached chernozem from the area of the Voronezh Agricultural Institute and chestnut soil from Karagandinskaya region. Ten grams of each of these soils was placed on a funnel with a filter and washed with 0.1 N solutions of the different salts until the adsorbed cations of the adsorbing complex of the soil had been completely displaced and saturation with the new cations had taken place. The following salts were used for displacement of the adsorbed cations: $FeCl_3$, $BaCl_2$, $CaCl_2$, NaCl and hydrochloric acid, HCl. The reaction to calcium was used as the criterion for complete displacement of the adsorbed cations and saturation of the adsorbing complex with the new cations. Following saturation of the soil by the different cations, the soil sample was washed with water to free it from the salts with which it had been treated. The sample and the filter were left in the laboratory to dry[1] and then were transferred to a flask to which was added 0.02 N ammonium sulfate at a ratio of 1:25. This was shaken and allowed to stand for 24 hours. It was then shaken again and filtered. Adsorption of $SO_4^=$ by the soil was determined by the difference in $SO_4^=$ content in the filtrate and in the original solution. The results of the experiment are shown in Table 1.

Natural (that is, untreated) soils of different types adsorbed insignificant quantities of the sulfate anion although not uniformly. The greatest amount was adsorbed by peat-podzolic soil; next was leached chernozem, and the least was adsorbed by chestnut soil. The amount of $SO_4^=$ adsorbed by all these soils changes sharply with complete saturation by separate cations. Here some cations increase and others decrease the amount of the sulfate anion absorbed. Thus, peat-podzolic soil saturated with Fe^{+++} adsorbed three times as much $SO_4^=$ as the same soil in its natural state. Peat-podzolic soil saturated with Ba^{++} adsorbed even more of this anion than the natural soil. The same soil saturated with Ca^{++}, adsorbed five times less $SO_4^=$ than did the barium-saturated soil, but still adsorbed almost twice as much as the natural soil. Peat-podzolic soil completely saturated with hydrogen ions adsorbed half again as much $SO_4^=$ as did calcium-saturated soil and three times as much as natural soil. The adsorptive capacity of the same soil when fully saturated with hydrogen ions approached that saturated with ferric ions. When peat-podzolic soil was saturated with sodium ions its adsorptive capacity for $SO_4^=$ went down sharply as compared to the other cations. Sodium-saturated soil adsorbed ten times less $SO_4^=$ than calcium-saturated soil and six times less than natural soil.

Thus, the amount of $SO_4^=$ adsorption by peat-podzolic soil saturated with different cations changes greatly.

Exactly the same picture was observed in leached chernozem, the only difference being that more $SO_4^=$ was adsorbed in it than in peat-podzolic soil.

Chestnut soil, when saturated with the different cations, showed the same effect of the exchangeable cations on the amount of $SO_4^=$ adsorbed as did the other two soils.

The amount of $SO_4^=$ adsorbed decreases with saturation of the soil by the cations in the following order:

$$Ba > Fe > H > Ca > Na$$

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[1] In calculating the amount of adsorbed sulfate ions the author did not introduce a correction for the soil moisture, with the result that the data obtained are somewhat too low. (Comment by editor of the Russian journal.)

TABLE 1

Adsorption of $SO_4^=$ by soils saturated by different cations in milliequivalents per 100 grams of soil

Soil	Fe^{+++}	Ba^{++}	Ca^{++}	H^+	Na^+	Natural soil
Peat-podzolic	97.5	242.5	52.5	80.0	5.2	32.5
Leached chernozem	147.5	922.5	62.5	90.0	7.0	20.0
Chestnut	67.5	335.0	23.5	32.5	10.5	10.7

The connection established between the amount of $SO_4^=$ adsorbed and the exchangeable cations is general for all soils and is completely regular. This regularity is explained by the nature of the exchangeable cations and the character of the bond between sulfate ions and the individual components of the soil. Thus, for example, the maximal adsorption of $SO_4^=$ by soils saturated with Fe^{+++} is explained by the fact that iron is bound to the adsorbing complex by only one of the valences leaving the others bound to $SO_4^=$. As a result the $SO_4^=$ is bound through the adsorbed iron to the adsorbing complex of the soil. When the soil is fully saturated with iron a certain amount of it is probably in the form of colloidal hydroxides binding $SO_4^=$ directly. In both cases the $SO_4^=$ bonding takes place by physicochemical means. Here a nonexchange type of adsorption of the $(NH_4)_2SO_4$ molecule as a whole is possible:

$$\text{(soil colloid)}\,\begin{matrix}\text{Fe}\\ \text{Fe}\end{matrix} + 3(NH_4)_2SO_4 \rightleftarrows$$

$$\text{(soil colloid)}\,\begin{matrix}NH_4 & NH_4\\ & NH_4\\ & NH_4\\ NH_4 & NH_4\end{matrix} + Fe_2(SO_4)_3$$

If colloidal ferric hydroxide is present in the soil the adsorption follows this outline:

$$\{[Fe(OH)_3]FeO\}\begin{matrix}Cl\\ Cl\end{matrix} + (NH_4)_2SO_4 =$$

$$\{[Fe(OH)_3]FeO\}SO_4 + 2NH_4Cl$$

The high adsorptive capacity of the soils saturated with Fe^{+++} is possibly also caused by the increased acidity of the soil which is created here.

The large amount of $SO_4^=$ adsorption by soils saturated with Ba^{++} is explained by the fact that $SO_4^=$ in the presence of Ba^{++} goes over completely to an insoluble form. The combination with $SO_4^=$ is participated in by the barium in the adsorbed state and by the barium which is present in the soil solution. The adsorption of $SO_4^=$ takes place according to the equation

$$\text{(soil colloid)Ba} + (NH_4)_2SO_4 =$$

$$\text{(soil colloid)}\begin{matrix}NH_4\\ NH_4\end{matrix} + BaSO_4$$

Such an equation also shows the process of the adsorption of $SO_4^=$ by soils saturated with calcium. The smaller amount of $SO_4^=$ adsorbed is explained by the fact that calcium cannot form such insoluble sulfates as barium.

The significant role of H^+ in the adsorption of $SO_4^=$ by soils is explained by the high acidity created making possible overcharging of the soil colloids and transition of the iron compounds into the mobile colloidal state. Both these processes which take place in the soil when it is strongly acidified also cause an increase in the adsorptive capacity of the soils with respect to the sulfate anion. Here the adsorption of $SO_4^=$ proceeds by physicochemical means. The negligibly small amount of adsorption of $SO_4^=$ by soils saturated with sodium ions is explained by the increased alkalinity which this creates. Comparing the amount of adsorption of $SO_4^=$ by soils saturated with Fe^{+++}, Ba^{++}, Ca^{++}, H^+ and Na^+ with that adsorbed by natural soils, we can confirm that the adsorptive capacity of all soils saturated with Fe^{+++}, Ba^{++}, Ca^{++} and H^+ is considerably higher than in natural soil. Soils saturated with sodium adsorbed less $SO_4^=$ in all cases than did natural soils.

The conclusions drawn with respect to the role of exchangeable cations in the adsorption of the sulfate anion are certainly correct but this role is not fully revealed if we grant that the amount of adsorbing complex in the different soils is the same, or if we consider that all of the soil mass takes part in the exchange reactions. Actually, the amount of the adsorbing complex is far from being uniform, as can be roughly judged by the amount of clay (that is, of particles less than 0.001 mm.) in the soils tested. To reveal more fully the role of exchangeable cations in the adsorption of $SO_4^=$ by various soils the calculation of the amount of adsorption should not be made on the basis of 100 grams of soil but on that of 100 grams of the clay contained in it. This would then provide values making it possible to clarify more fully the role of the separate cations in the adsorption of $SO_4^=$. Data characterizing the role of the exchangeable cations in the adsorption of

$SO_4^=$ by the clay of the different soils are shown in Table 2.

Recalculation of the amount of $SO_4^=$ adsorbed on clay shows quite an interesting picture. The clay of peat-podzolic soil adsorbed the greatest amount of $SO_4^=$ in comparison with the other soils. The clay of leached chernozem adsorbed 6.5 times less $SO_4^=$ than the clay of peat-podzolic soil, and the clay of the chestnut soil adsorbed twice as much as the clay of the leached chernozem. Thus the clays of different soils have different adsorptive capacities for $SO_4^=$ which shows that they are of different qualitative composition.

The effects of the different exchangeable cations on the adsorption of $SO_4^=$ by clay vary more widely than they do in whole soil. The clay fraction of peat-podzolic soil saturated with Fe^{+++} adsorbs three times as much $SO_4^=$ as the original clay of the same soil. Clay saturated with Ba^{++} adsorbs almost eight times as much as the original clay of the same soil, but the clay saturated with Ca^{++} adsorbs only 1.5 times as much. The clay fraction of the peat-podzolic soil saturated with H^+ adsorbs 2.5 times as much $SO_4^=$ as the original clay; sodium-saturated clay adsorbs six times less $SO_4^=$ than the original. The clay fraction of the leached chernozem saturated with the same elements adsorbs less $SO_4^=$ than the clay fraction of the peat-podzolic soil; but the effect of the individual cations remains the same. The clay fraction of the chestnut soils, when saturated with the different cations, adsorbed less than did the clay fraction of the peat-podzolic soil but more than that of the leached chernozem.

Thus the exchangeable cations involved in the adsorption of $SO_4^=$ by clay are distributed in the same order as for whole soil.

From the data on the adsorption of $SO_4^=$ by clay of different soils saturated with individual cations it is seen that the activity of the clay, and consequently of the adsorbing complex of the soils tested, is not the same. The clay most actively adsorbing $SO_4^=$ was that from the peat-podzolic soil, while that from the chestnut soil was less active and that from the leached chernozem was still less active.

To define more accurately the form of adsorption of $SO_4^=$ and to clarify our concept of the nature of the adsorption, we carried out a supplementary experiment in the adsorption of $SO_4^=$ by soils saturated with different cations. In it we calculated not only the adsorption of $SO_4^=$ but also that of NH_4^+ in the case of $(NH_4)_2SO_4$ and of that of H^+ in the case of H_2SO_4. The method in this experiment is similar to that of the preceding experiment. The soil was leached chernozem from the Voronezh Agricultural Institute.

TABLE 2

Adsorption of $SO_4^=$ by soils saturated with different cations in milligrams per 100 grams of clay

Soil	Fe^{+++}	Ba^{++}	Ca^{++}	H^+	Na^+	Clay of natural soil	Natural soil
Peat-podzolic	1301.7	3237.6	700.9	1068.0	69.42	433.9	32.5
Leached chernozem	486.1	3040.5	205.9	296.6	23.07	65.92	20.0
Chestnut	843.7	4437.0	293.5	406.2	131.2	133.7	10.7

TABLE 3

Adsorption of $SO_4^=$ from ammonium sulfate and sulfuric acid in milliequivalents Per 100 grams of soil

Subject of investigation	$(NH_4)_2SO_4$		H_2SO_4	
	$SO_4^=$	NH_4^+	$SO_4^=$	H^+
Natural soil	0.385	5.383	1.466	30.07
Fe-saturated soil	2.833	9.76	4.375	14.45
Ba-saturated soil	17.85	18.88	24.68	35.35
Ca-saturated soil	1.26	6.088	1.677	30.80
H-saturated soil	1.572	3.411	2.395	7.95
Na-saturated soil	0.104	9.625	1.25	30.72

In resolving this question, we expressed the results of the experiment (that is, the amount of adsorption of anions and cations) in the form of milliequivalents per 100 grams of oven-dry soil (Table 3).

From Table 3 it is seen that a soil saturated with any cation adsorbs a greater amount of cations than of anions from ammouium sulfate solution and from sulfuric acid. The ratio between the adsorbed cations and anions in soils saturated with different cations is not uniform. The widest ratio was seen in sodium-saturated soil, the narrowest in barium- and hydrogen-saturated soils. Adsorption takes place by physicochemical means. Anions and cations were adsorbed simultaneously but the cations were adsorbed with greater energy than the anions.

The extremely similar data on the adsorption of $SO_4^=$ and NH_4^+ in barium-saturated soil shows that a chemical absorption is taking place in addition to the physicochemical $SO_4^=$ adsorption reaction. Barium, being displaced by ammonium from the colloidal complex, immediately combines with $SO_4^{=}$ to form barium sulfate. Calcium-saturated soil adsorbs $SO_4^{=}$ by the same means as barium-saturated soil. The only difference is that the amounts adsorbed are considerably smaller because the compounds formed in this process are less stable. Hydrogen-saturated soil adsorbs $SO_4^{=}$ from the solution chiefly through the exchange reaction between the positively charged colloids and the sulfuric acid or ammonium sulfate. When the soil is saturated with sodium it is principally the adsorption of NH_4^+ which takes place; there is only negligible adsorption of $SO_4^{=}$. This is probably caused by phenomena of a mechanical nature when the colloids are flocculated.

From all the information presented previously, it is evident that exchangeable cations play an extremely substantial role in the adsorption of the sulfate anion. The amount of adsorption undergoes great changes depending on the character of the exchangeable cation. From this the practical conclusion emerges: if necessary the amount of adsorbed $SO_4^{=}$ can be changed in either direction by changing the composition of the exchangeable cations in the soil.

It is highly probable that the amount of $SO_4^{=}$ in the soil solution of natural soils depends to some degree on the character and composition of the exchangeable cations, while the dynamics of $SO_4^{=}$ observed in the soil (2) is explained not only by the biological processes taking place but also by changes in the composition of the exchangeable cations of the soils at the time.

Conclusions

1. Soils (peat-podzolic, leached chernozem, and chestnut) saturated with iron, barium, calcium, and hydrogen have a higher adsorptive capacity for sulfate ions than the corresponding natural soils; but soils saturated with sodium in all cases adsorb less sulfate ions than natural soils. The exchangeable cations are in the following descending order with respect to the size of their effect on $SO_4^{=}$ adsorption: $Ba > Fe > H > Ca > Na$.

2. Soils saturated with iron adsorb $SO_4^{=}$ chiefly by physicochemical means, while barium- and calcium-saturated soils do this by physicochemical and chemical means. The adsorption of sulfate ions by sodium-saturated soil is probably caused by phenomena of a mechanical nature when the colloids are flocculated.

3. The experiments carried out are evidence that the amount of sulfate ions in the soil solution of natural soils depends on the composition of exchangeable cations. This idea can be used for practical purposes.

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COLORIMETRIC METHODS FOR DETERMINING PHOSPHORUS IN ACID EXTRACTS OF SOILS

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The basis of the colorimetric determination of phosphorus by the blue color method is the ability of phosphorus when placed in a solution of ammonium phosphomolybdate at a definite acid pH to form heteropoly acids of the composition $H_7[P(Mo_2O_7)_6] \cdot nH_2O$.[1] If a reducing agent is added to the solution of phosphomolybdic acid, its hexavalent molybdenum component is partially reduced to the pentavalent form thereby forming the so-called phosphomolybdenum blue and coloring the solution light-blue. To obtain great accuracy in the phosphorus determination the analytical conditions must be selected in such a way that only the molybdenum bound to phosphorus is reduced, and not the remainder which is in excess in the solution in the form of ammonium molybdate. This is achieved by a definite ratio of the reagents: a mineral acid (H_2SO_4, HCl), ammonium molybdate, and a reducing agent (stannous chloride, hydrazine sulfate, hydroquinone, and so forth).

In 1920 Denigès (31) suggested the determination of phosphorus by the use of the phosphomolybdenum blue method. He used stannous chloride as the reducing agent. Many investigators (10, 11, 24, 26, 32, 35, 37, 40) have stated that in Denigès' method proportionality is not achieved between the intensity of the coloration and the concentration of phosphorus in the solution. This caused the appearance of a number of modifications of the original version of Denigès' method. The use of different modifications of this method in the colorimetric determination of phosphorus makes it difficult to compare the analytical data obtained.

In the present paper we compare the results of phosphorus determinations in acid extracts of soils by the use of the following modifications of Denigès' method: A. Shmuk and M. Kurilo (26), A. Yu. Levitskii (10), A. Malyugin and E. Khrenova (11), E. Truog and A. Meyer[2] (35), Sh. P. Tsintsadze (24, 40), Dickman and Bray (32), M. L. Tsap (22), and A. M. Meshcheryakov (12).

Table 1 shows the amount of acid and MoO_3 and the ratio between these reagents recommended in the modifications of Denigès' method listed above. From these data it is seen that there are considerable differences in the absolute quantities of acid and MoO_3 added to 100 ml. of the solution under test in the different modifications of Denigès' method; but for most of the versions (excepting those of Dickman and Bray, Tsintsadze and Meshcheryakov) the ratios of these reagents are extremely close.

To compare the results of the phosphorus determinations by the various modifications of Denigès' method five samples of surface soils of different types were taken from each of which the following four acid extracts were prepared: 0.5 N CH_3COOH according to Chirkov (25); 0.002 N H_2SO_4 according to Truog (36); 1% citric acid, according to Arrhenius in the version by Ginzburg (7); and 0.2 N HCl according to Kirsanova (21). In the soil extracts obtained the phosphorus was determined colorimetrically by the use of different modifications of Denigès' method (*vide supra*). All the phosphorus determinations were carried out with a model FEK-M photocolorimeter using a red filter.

The analytical data listed in Tables 2 and 3 show a very close agreement in the quantities of phosphorus determined in the acid extracts of the soils by various modifications of Denigès' method.

Simultaneously, comparative determinations of the phosphorus content were made in hydrochloric and sulfuric acid extracts of the soils using the ammonium molybdate solution prepared with hydrochloric acid (Dickman-Bray modification; see Table 2). The data obtained

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[1] In this paper coordination formulas of the heteropoly acids are given, in contrast to the other formulas proposed in the literature which are based on certain structural x-ray analytical data (2, 8, 14, 15, 16, 28, 38).

[2] Determination of phosphorus by the Truog-Meyer version was checked gravimetrically by the Lorentz method. The results of analysis by the two methods agreed; for this reason we took the Truog-Meyer version as a standard for checking the remaining versions of Denigès' method.

TABLE 1

Quantities of acid and MoO_3 added to the solution to be analyzed in different modifications of Deniges' method; also the ratio of these quantities

As modified by:	Mg./100 g. of solution		Ratio acid
	H_2SO_4 or HCl	MoO_3	MoO_3
Shmuk & Kurilo	750	47.5	16
Levitskii	2200	118.8	18
Malyugin & Khrenova	2700	190.2	14
Truog & Meyer	2000	95.2	21
Dickman & Bray	2560[a]	285.3	9
Tsintsadze	464	15.1	30
Tsap	5000	273	18
Meshcheryakov (first & second)	454	15.1	30

[a] In this case HCl, but in all the remaining modifications H_2SO_4.

show that in hydrochloric acid extracts of the soil it is possible to determine the phosphorus content by using ammonium molybdate reagent prepared with either hydrochloric or sulfuric acid. In determining the phosphorus content of the sulfuric acid extracts of the soils, the use of ammonium molybdate solution prepared with hydrochloric acid is undesirable because in most cases this gives too high a quantity of phosphorus in the extract (Table 2).

Notes on Individual Versions of Denigès' Method

A. Yu. Levitskii Version. a) The solution of ammonium molybdate prepared according to the author's precise instructions turns blue in 7 to 14 days after its preparation (and sometimes sooner) and becomes unsuitable for use. Evidently the development of the blue color in the reagent is connected with the presence of a reducing agent in the concentrated sulfuric acid in the form of an impurity (possibly partially unoxidized SO_2 from the sulfuric acid production process). b) The reducing agent is prepared in the form of a "copper-tin buffer reducing agent." The purpose of using such a reducing agent is to produce a stable phosphomolybdenum blue coloration. In a practical check it appeared that the addition of an excess of copper sulfate to the stannous chloride solution only complicates the preparation of the reducing agent and gives no advantages over the formulas of other versions of Denigès' method. A. Malyugin and E. Khrenova also noted this.

A. Malyugin and E. Khrenova Version. a) The aqueous solution of ammonium molybdate in the Malyugin-Khrenova version is prepared separately from 27% H_2SO_4. The shelf life of the reagent is two weeks. The storage period can be prolonged to six months or more if the ammonium molybdate solution is mixed with the 27% H_2SO_4 solution just before use. b) For a single phosphorus determination it is recommended that 5 ml. of a 2% solution of ammonium molybdate and 5

TABLE 2

Determination of phosphorus content by different versions of the Denigès method in acid extracts of soils (data in mg. of P_2O_5 per 100 g. of soil)

Soil designation	0.5 N CH_3COOH				0.2 N HCl					0.002 N H_2SO_4					1 % citric acid			
	Shmuk Kurilo	Levitskii	Malyugin Khrenova	Truog Meyer	Shmuk Kurilo	Levitskii	Malyugin Khrenova	Truog Meyer	Dickman Bray	Shmuk Kurilo	Levitskii	Malyugin Khrenova	Truog Meyer	Dickman Bray	Shmuk Kurilo	Levitskii	Malyugin Khrenova	Truog Meyer
Thick fine clay loam chernozem (Kursk Zonal Experiment and Soil Improvement Station), sample 1	8.5	9.0	9.0	9.0	19.0	20.5	20.0	18.0	19.5	10.9	13.5	13.0	12.5	16.6	11.5	11.3	12.0	12.0
Gray forest soil (Uzunovo, Moscow region), sample 1	11.0	11.5	11.5	12.0	12.0	14.0	13.0	14.0	15.5	11.7	13.0	12.0	14.0	19.0	12.0	12.3	14.3	13.5
Peat-podzolic medium clay loam (Dolgoruchnaya Agricultural Chemical Experiment Station), sample 1	4.3	4.5	4.5	4.5	12.0	13.5	12.5	12.5	11.0	7.5	8.0	8.0	9.0	11.2	12.8	14.0	17.0	15.3
Krasnozem (Anaseuli, Institute of Tea and Subtropical Crops), fertilized 3 × with super phosphate P_2O_5 @ 480 kg./ha., sample 1	3.7	4.0	4.1	4.4	15.0	16.0	15.5	15.5	16.2	13.7	16.0	13.5	16.0	19.2	12.5	12.0	12.0	13.5
Slightly podzolized zheltozem (Lenkoran, Azerbaidzhan SSR)	18.0	20.0	20.0	18.0	30.7	34.0	33.0	35.0	37.3	25.0	26.0	26.0	28.0	35.3	25.5	24.0	27.0	27.5

TABLE 3

Determination of phosphorus content by different versions of the Denigès method in acid extracts of soils (data in mg. of P_2O_5 per 100 g. of soil)

Soil designation	0.5 N CH_3COOH					0.2 N HCl					0.002 N H_2SO_4					1% Citric Acid				
	Truog Meyer	Tsintsadze	Tsap	Meshcheryakov I	Meshcheryakov II	Truog Meyer	Tsintsadze	Tsap	Meshcheryakov I	Meshcheryakov II	Truog Meyer	Tsintsadze	Tsap	Meshcheryakov I	Meshcheryakov II	Truog Meyer	Tsintsadze	Tsap	Meshcheryakov I	Meshcheryakov II
Thick fine clay loam chernozem (Kursk Zonal Experimental & Soil Improvement Station), sample 2	15.0	13.5	15.0	20.0	11.5	25.5	27.0	27.5	20.3	21.0	15.5	17.0	25.0	25.0	17.0	22.0	20.5	22.5	25.5	19.0
Peat-podzolic medium clay loam (Dolgoruchnaya Agricultural Chemical Experimental Station), sample 2	1.8	1.8	2.1	3.8	1.9	5.0	6.0	5.5	11.7	6.5	5.0	6.0	6.3	10.0	6.5	11.0	10.0	9.2	14.5	13.3
Gray forest soil (Uzunovo, Moscow region), sample 2	3.1	2.6	3.2	3.3	3.1	13.0	11.5	12.5	13.5	11.3	8.5	10.5	6.3	10.0	8.5	25.0	21.0	25.0	25.8	27.5
Krasnozem from Anaseuli, fertilized 3 × with superphosphate P_2O_5 @ 240 kg./ha., sample 2	0.8	0.9	1.1	2.2	1.3	3.4	2.6	4.2	6.7	4.5	4.3	5.2	6.3	6.5	5.3	8.5	7.5	8.2	12.5	7.8

ml. of 27% H_2SO_4 be placed in 50 ml. of the solution to be tested. Thus the total volume of the reagents to be added is 10 ml. When the extract contains only a little phosphorus (and as a result a large aliquot of it must be used for the phosphorus determination) the addition of such a large volume of the reagents as 10 ml. makes the determination more difficult. c) The preparation of the reducing agent is a long and painstaking procedure. The reducing agent does not tolerate storage well. It is simpler and more desirable to prepare a 1% solution of $SnCl_2$ (as Sn) on the day of the phosphorus determination by dissolving 0.16 g. of $SnCl_2 \cdot 2H_2O$ in 10 ml. of 10% HCL or 0.1 g. of metallic tin in 2 ml. of concentrated HCl with one or two drops of 10% $CuSO_4$ on a water bath; in the latter case after the tin has dissolved and the solution has cooled it is made up to a total volume of 10 ml. with distilled water. d) The authors consider that with this modification it is possible to determine from 0.004 to 5.0 mg. of P_2O_5 in 100 ml. of solution.

We established experimentally that in determinations of phosphorus by the methods of Shmuk and Kurilo, Levitskii, Malyugin and Khrenova and Truog and Meyer the compliance of the colored solution with the Bouguer-Lambert-Beer law (9, 27)—that is, the optical density or intensity of coloration of the solution as a function of the ion being determined—was retained if 100 ml. of the test solution contained from 0.005 to 0.14 mg. of P_2O_5.

Truog and Meyer Version. a) The solution of ammonium molybdate in sulfuric acid keeps for a year or more. b) For a reducing agent the authors recommend the use of 25 g. of $SnCl_2 \cdot 2H_2O$ dissolved in 1 liter of 10% HCl. The solution is placed in a bottle with a siphon and preserved under a 5 mm. layer of mineral oil. Under these conditions the reducing properties of $SnCl_2$ are preserved for 10 to 14 days. A more desirable $SnCl_2$ solution is prepared on the day of the determination of phosphorus by dissolving 25 g. of the salt in (sic) 10 ml. of 10% HCl, which is enough for 60 to 70 determinations of phosphorus in 50 ml. of solution. The hydrochloric acid solution of $SnCl_2$ may be kept in small (10 to 20 ml.) flasks with ground glass stoppers. They must be filled absolutely full with the solution of the reducing agent to completely displace traces of air from the flask, after which they must be tightly closed and kept in a dark place. One such flask will last for a series of determinations over a period of 8 to 12 hours. Any of the solution remaining unused is poured out because on the next day it will not be suitable for use (17).

Dickman and Bray Version. a) When the test solution contains less than 0.03 mg. of P_2O_5 per 100 ml. the color produced is green; but with P_2O_5 content between 0.03 and 0.16 mg. per 100 ml. the color produced is blue, however, it retains a negligible green tinge. A similar green coloration of solutions containing very little phosphorus is also produced in colorimetric phosphorus determinations by the method of A. T. Kirsanov (in this method the ammonium molybdate solution is also made up with hydrochloric acid). There are references in the literature (20) to the fact that solutions of molybdates in hydrochloric acid in the presence of salts of alkali metals and of a reducing agent may form chlorine compounds with the formula $M_2(MoCl_5)$ which have a green color, and which in this case may serve as one of the sources of the green tinges of the colored solutions. It is also known (3, 8) that large quantities of Cl^- ions in the solution may destroy the phosphomolybdate complex and thus interfere with the phosphorus determination. Therefore, in our opinion, the use of ammonium molybdate solutions made up with hydrochloric acid (in any of the modifications) are undesirable for the colorimetric determination of phosphorus by the blue color method.

Sh. R. Tsintsadze Version. a) The MoO_3 preparation is made by heating ammonium molybdate in a muffle furnace at 450° C. for 3 to 4 hours. This procedure can be carried out on a gas burner; the NH_4^+ ion volatilizes at a lower temperature (180° to 200° C.). b) The coloration of the phosphomolybdenum blue in acid soil extracts and in the series of sample solutions of KH_2PO_4 lasts only for about 15 to 20 minutes, not for two hours, as the authors state.

The method is extremely sensitive and can determine 0.003 mg. of P_2O_5 in 100 ml. of solution.

L. M. Tsap Version. This method is not suitable for the visual determination of phosphorus. a) To produce stable colored solutions this author uses a hydrazine sulfate solution as the reducing agent. The reduction takes place for 20 minutes on a water bath in 1.0 N H_2SO_4 to which a large excess of MoO_3 has been added. Under these conditions a control solution not containing phosphorus is colored yellow-orange. The solutions to be analyzed, if they contain less than 0.03 mg. of P_2O_5 in 50 ml. of solution, are also colored yellow-orange. Solutions containing more than 0.03 mg. of P_2O_5 in 50 ml. are a dirty greenish color. The sensitivity of this version is lower than that of the other vesions of the Denigès method referred to previously. The analysis is unwieldy, requires painstaking work, and is little suited to large-scale analysis of soil extracts.

The unsuccessful shades of the colored solutions in this version are probably caused by carrying out the reduction at very high acidity of the solution (1 N).

According to the data of A. K. Babko and L. M. Evtushenko (5), when the acidity of the solution is above 0.9 N destruction of the blue phosphomolybdate complex begins, regardless of the reducing agent used. However, we cannot agree with the lower limit of allowable acidity of the solution for the reducing agent $SnCl_2$ of 0.8 to 0.9 N. A widely used method for the colorimetric determination of phosphorus (see Table 1) uses a maximum acidity of the solution of about 0.5 N (the Malyugin-Khrenova version), and in the Tsintsadze version the acidity of the solution is 0.09 N. Incidentally, in these versions a solution of ammonium molybdate without phosphorus does not turn blue on adding the reducing agent $SnCl_2$; and the results of the determination of phosphorus in acid soil extracts obtained by these methods are very satisfactory (Tables 2 and 3).

A. M. Meshcheryakov's First Version. This is based on Tsintsadze's version but uses a 5% solution of thiourea as a reducing agent to produce a stable colored solution. Reduction is carried out for 30 minutes on a water bath and in the process the colored solution becomes turbid and sulfur precipitates. The author recommends filtering it off and washing the filter with distilled water or allowing the colored solution to stand until the next day to allow the turbidity to settle. The method is cumbersome and also is not suitable for large-scale analyses of soil extracts. The version is not sensitive enough since it makes possible the determination of only 0.02 to 0.06 mg. of P_2O_5 in 50 ml. of solution. (Its sensitivity is about 10 times less than Tsintsadze's version.)

Meshcheryakov's Second Version. a) To obtain a stable phosphomolybdenum blue coloration, a composite reducing agent $SnCl_2$ + thiourea is used. Reduction takes place in the cold. Many checks of this version have established (see Fig. 1, a and b) that the maximum phosphomolybdenum blue coloration is reached 15 minutes after adding $SnCl_2$ to the solution being tested; after 30 minutes its intensity decreases by an average of 5 to 8%, and after an hour by 11 to 15%. During the following hour the color remains constant, but then its intensity falls again by 17 to 25%.

On the basis of the analytical data obtained, the determination of phosphorus in solution by Meshcheryakov's second version can be expediently carried out an hour after adding $SnCl_2$ and also during the succeeding hour. By this version

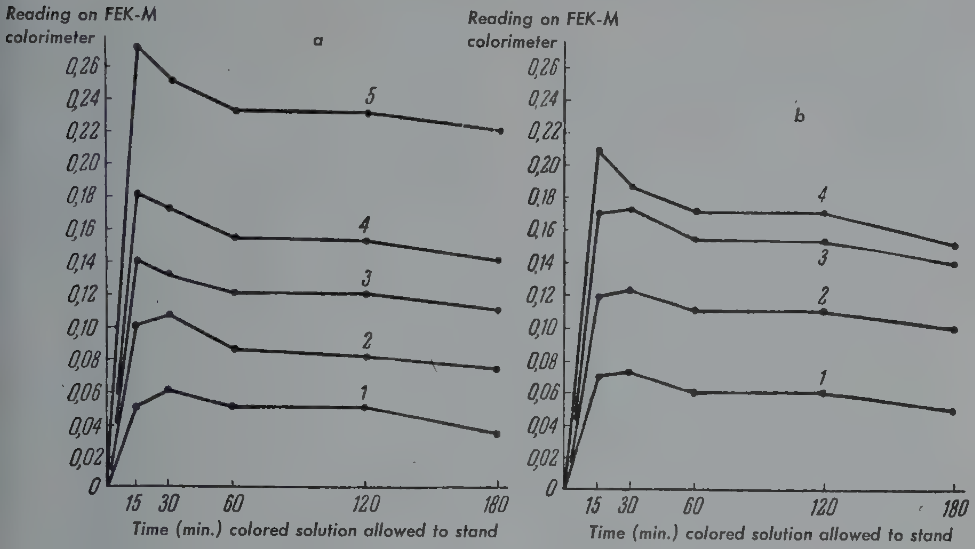

FIG. 1.—Stability of the phosphomolybdenum blue color with time in the second version of Meshcheryakov. a—In sample solutions of KH_2PO_4 (mg. of P_2O_5 in 50 ml.): 1—0.01; 2—0.02; 3—0.03; 4—0.04; 5—0.06. b—In acid extracts of peat-podzolic soil (from the Dolgoruchnaya Agricultural Chemical Experiment Station): 1—0.002 N H_2SO_4; 2—0.5 N CH_3COOH; 3—0.2 N HCl; 4—1% citric acid.

0.01 to 0.06 mg. of P_2O_5 in 50 ml. of solution can be determined.

Effect of Different Ions on the Colorimetric Determination of Phosphorus in Solution by the Blue Color Method

As mentioned previously, substances forming complexes with MoO_3 (8, 14, 28) also destroy phosphomolybdic acid (ions of oxalic and citric acid, trivalent iron, and fluorine; in large quantities, Cl^- and other ions). In the colorimetric determination of phosphorus, the solution being examined must not contain these ions in quantities which interfere with the determination. To this end, the extract or solution is treated by appropriate means (oxidation, evaporation, and so forth) before the colorimetric determination of phosphorus in the extract or solution is examined.

Effect of Fe^{+++} Ions. When various acid extracts of the soil are prepared Fe^{+++} ions contained in the soil in acid-soluble form may go into the solution along with the phosphorus. Depending on the experimental conditions the iron may interfere with the determination of phosphorus by the blue color method either by participating in the oxidation-reduction system (phosphomolybdate complex $\rightleftarrows$ phosphomolybdenum blue)—in which the color of the phosphomolybdenum blue formed becomes unstable and quickly fades, or by forming a complex with the heteropoly acid $H_9[Fe(MoO_4)_6]$—in which case addition of the reducing agent to the solution being examined causes the latter to turn green; or both these processes may take place at the same time (33, 37).

In an earlier paper (7) it was established that iron interferes with the colorimetric method of phosphorus determination by the blue color method (version of Truog and Meyer) if more than 1.8 mg. of Fe^{+++} is contained in 50 ml. of the solution being examined. At the same time it was shown that when *mobile* phosphorus is being determined in slightly acid extracts of soils, the iron is dissolved in the solution in quantities which do not interfere; but in the determination of *total* soil phosphorus the amount of iron going into solution does interfere and requires previous removal of the iron from the solution. Removal of the iron present in the solution may be accomplished by several methods (29, 30, 32, 33, 37, 39). The method of Warren and Pugh (21, 39) must be considered to be the most successful of them.

Effects of Al^{+++}, Mn^{++}, Ca^{++} and Mg^{++}. Ac-

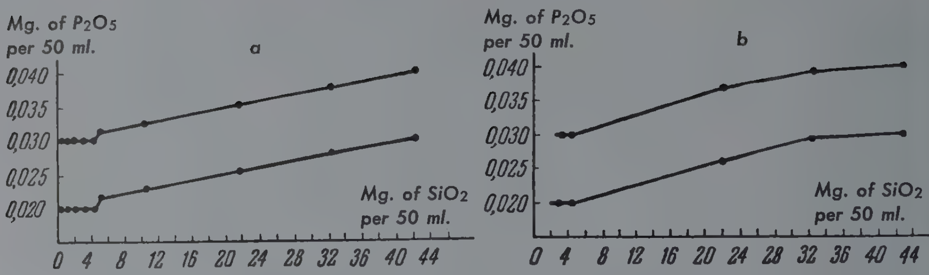

FIG. 2.—Effect of SiO_2 on the colorimetric determination of phosphorus by the blue color method. a—Molybdate solution poured into the solution being tested; b—solution being tested poured into molybdate solution.

cording to the data of Truog and Meyer, salts of Al, Mn, Ca and Mg may be present in the solution in considerable quantities (up to 100 mg. per 100 ml. of solution) without effect on the phosphomolybdenum blue color.

Effect of Arsenic. Arsenic acid forms exactly the same kind of a heteropoly acid with MoO_3—$H_7[As(Mo_2O_7)_6]$—as does phosphoric acid, and under the same conditions. For this reason, if even a trace of arsenic is present in the solution (which sometimes happens in analyses of samples of soils treated by "insectofungicides") it will interfere with the determination. In the determination of phosphorus in solutions containing arsenic acid, the latter is reduced (with H_2S, Na_2S in acid solution, KBr, and so forth) to arsenous acid, and then phosphorus is determined by the usual method (22, 24, 35, 40).

The Effect of SiO. The colorimetric determination of phosphorus may be interfered with by silicic acid which, like phosphoric acid but under slightly different conditions, forms a heteropoly acid—$H_8[Si(Mo_2O_7)_6]$—with MoO_3.

To eliminate the harmful action of silicic acid, Chapman (30) recommended pouring the solution being examined into a solution of ammonium sulfomolybdate in order to avoid the formation of silicomolybdate which (he says) is not formed in the strongly acid solution. Actually, there are statements in the literature to the effect that silicomolybdic acid is formed at a lower degree of acidity than is phosphomolybdic acid (5, 23, 38), but there are other data (4) showing that the silicomolybdic complex like the phosphomolybdate complex is formed in a strongly acid solution at a pH of less than 2. Here, if the silicomolybdate complex in the solution has already been formed, then, in contrast to the phosphomolybdic complex, it is resistant to the subsequent addition of strong acids and complex-formers such as citric, oxalic and tartaric acids, and so forth. This is the basis for determining SiO_2 in the presence of phosphorus.

We made a study of the amount of silicic acid which interferes with the determination of phosphorus by the Truog and Meyer version of Denigès' method, both by the usual method of adding ammonium sulfomolybdate to the solution being tested (Fig. 2a) and by adding the solution being tested to ammonium sulfomolybdate as suggested by Chapman (Fig. 2b). As seen from Figure 2a and b, regardless of the order in which the solution being tested and the reagent are mixed, silicic acid interferes with the determination of phosphorus when there is more than 4 mg. of silicic acid in 50 ml. of solution.

Table 4 shows the silicic acid content in the acid extracts of the same soil samples in which the phosphorus content was determined (see Tables 2 and 3). As shown by the data of Table 4, the greatest amount of silicic acid was taken into the citric acid extract of gray forest soil (180 mg. of SiO_2 per 100 g. of soil). But in the volume of extract which was taken from this sample for the determination of phosphorus, there is only 0.3 mg. of SiO_2. As shown above in Figure 2a, this quantity of SiO_2 does not interfere with the determination of phosphorus. Thus, SiO_2 interferes when the SiO_2 is present in quantities 100 to 200 times larger than the P_2O_5 content in the solution—a situation which is almost never encountered when the usual acid extracts of soils are used. For this reason when phosphorus is determined colorimetrically in acid extracts of soils the previous precipitation of SiO_2 is not necessary. The results obtained agree with the data of other authors in the literature (6, 24, 26, 30, 35, 40).

Effect of the Fluorine Ion. F^- interferes with the determination of P_2O_5 by the blue color method. L. T. Kurtz (34) eliminates this action of the F^- ion by the addition of 0.8 mole of H_3BO_3 to the solution being tested. This causes the formation of fluoroborate—HBF_4— which does not interfere with the phosphorus determination. When this is done, the same reagents (except phosphorus) should be added to a control flask as are added to the solution being tested, since under some experimental conditions (large excess of the reagent) H_3BO_3 may form a heteropoly acid—$H_9[B(Mo_2O_7)_6]$—with ammonium molybdate and interfere with the phosphorus determination (8, 14, 28).

Determination of Phosphorus Combined with Organic Substances. Phosphorus which is bound to organic substances does not form a complex with MoO_3 and for this reason cannot be determined by the blue color method. To determine the phosphorus content of organic compounds the solution being tested must first be oxidized to destroy or ignite the organic matter. There are a number of methods of previous solution treatment being tested. The commonest and most effective are as follows: 1. Treatment with aqua regia (3 parts of HCl + 1 part of HNO_3). 2. Boiling or evaporation with an aqueous solution of perchloric acid, $HClO_4$ (50 to 70%). 3. Evaporation with concentrated HNO_3 + H_2O_2 (phosphorus-free). 4. Ignition in a muffle furnace after previously combining the phosphorus with Ca^{++} or Mg^{++} [calcium or magnesium acetate or $Mg(No_3)_2$] to minimize its tendency to volatilize so that heating up to 700° can take place without loss. For complete oxidation of the organic matter an excess of $KMnO_4$ should be added to the solution under test. If the oxidation takes place in sulfuric or nitric acid then any remainder of unused $KMnO_4$ is destroyed by adding a reducing agent to the solution—oxalic acid, glucose, ascorbic acid, thiourea, and so forth. In hydrochloric acid solution the excess of $KMnO_4$ would be reduced by the HCl which is capable of being oxidized to Cl_2 ; in this case enough HCl should be taken to combine with the K and Mn and to reduce the excess of $KMnO_4$. The method for the oxidation or combustion of the organic matter may be selected as appropriate for the working conditions and the subject of the analysis.

TABLE 4

Determination of SiO$_2$[a] content (given as mg. of SiO$_2$ per 100 g. of soil) in acid and aqueous extracts of soils

Soil designation	Extracts of soils				
	Aqueous	0.5 N CH_3COOH	0.2 N HCl	0.002 N H_2SO_4	1% citric acid
Thick, fine-textured clay-loam chernozem (Kursk region, Kursk Zonal Agricultural Chemical Experimental Station, sample 2	4.9	107.5	46.8	49.0	160.0
Gray forest soil (Uzunovo, Moscow region)	4.9	60.0	31.0	49.0	180.0
Peat-podzolic medium clay loam, (Dolgoruchnaya Agricultural Chemical Experimental Station, Moscow region)	1.5	17.1	8.0	41.0	150.0
Krasnozem fertilized 3 × with superphosphate P_2O_5 at 480 kg./ha. (Anaseuli, Institute of Tea & Subtropical Crops)	1.3	24.8	absent	16.0	60.0

[a] SiO$_2$ was determined by the Rode version of the Isaacs method (19).

Determination of Phosphorus in Citric and Acetic Acid Extracts. In the colorimetric determination of phosphorus in citric acid soil extracts the citric acid should first be oxidized since it prevents the formation of the phosphomolybdate complex (7). In that paper verification was provided for the need of previous evaporation and oxidation of acetic acid extracts before the colorimetric determination of phosphorus in them.

The data given in Table 5 allow us to recommend the determination of phosphorus in acetic acid extracts of soils without previous evaporation or oxidation of the solution if the latter is kept in quantities up to 20 ml. in 50 ml. volumetric flasks.

Development of the Phosphomolybdenum Blue Color with Time. A study was made of the stability of the blue color of solutions with time in the determination of phosphorus in a series of standard KH_2Po_4 solutions (Fig. 3a) and in acid extracts of soils (Fig. 3b) by the Truog-Meyer version.

In determining phosphorus in KH_2PO_4 solu-

TABLE 5

Effect of different versions of the preliminary treatment of 0.5 N CH_3COOH extracts on the results of phosphorus determinations (data in mg. of P_2O_5 per 100 g. soil)

Soil designation	P_2O_5 in extract		
	Without preliminary treatment	Evaporation	Evaporation & oxidation
Thick fine clay loam chernozem (Kursk Zonal Experimental & Soil Improvement Station) sample 3	17.5	17.7	18.1
Same, sample 4	13.7	14.9	14.6
Peat-podzolic medium clay loam without P_2O_5 fertilizer (Moscow region, Collective farm "Kolos")	8.5	8.9	9.3
Same with 45 kg./ha. P_2O_5	10.3	11.1	11.5
Krasnozem from Anaseuli, no fertilizer	absent	0.25	0.25
Same, fertilized 3 × with superphosphate P_2O_5 @ 480 kg./ha.	3.4	4.0	3.8
Same, fertilized 3 × with superphosphate P_2O_5 @ 960 kg./ha.	9.9	10.4	10.1

tions containing 0.05 to 0.01 mg. of P_2O_5 in 50 ml. the color is stable for an hour; with 0.01 to 0.02 mg. P_2O_5 in 50 ml. it is stable for 30 minutes; and with more than 0.02 mg. it is stable for 15 minutes after adding the reducing agent. It is possible that in more concentrated solutions of phosphate there is partial destruction of the phosphomolybdate complex under the influence of PO_4—which may replace a part of the coordination ion Mo_2O_7—and form a colorless complex compound (4).

Figure 3b shows the development of the phosphomolybdenum blue color with time in acid extracts of the surface layer of sod-podzolic soil. The development of color in these extracts of other soils was the same. From Figure 3b it is seen that in the acetic, sulfuric, and hydrochloric acid extracts of soils the color of the solutions reaches a maximum 5 minutes after adding the reducing agent, then from 15 minutes it remains unchanged and thereafter begins to fade; in citric acid extracts of soils the color of the solution reaches a maximum after 5 minutes and remains without change from 10 minutes after adding the reducing agent.

The instability of the blue color of solutions of acid extracts of soils is evidently related to the appearance in the extract of other ions in addition to phosphorus; these other ions, as stated, can participate in the oxidation-reduction

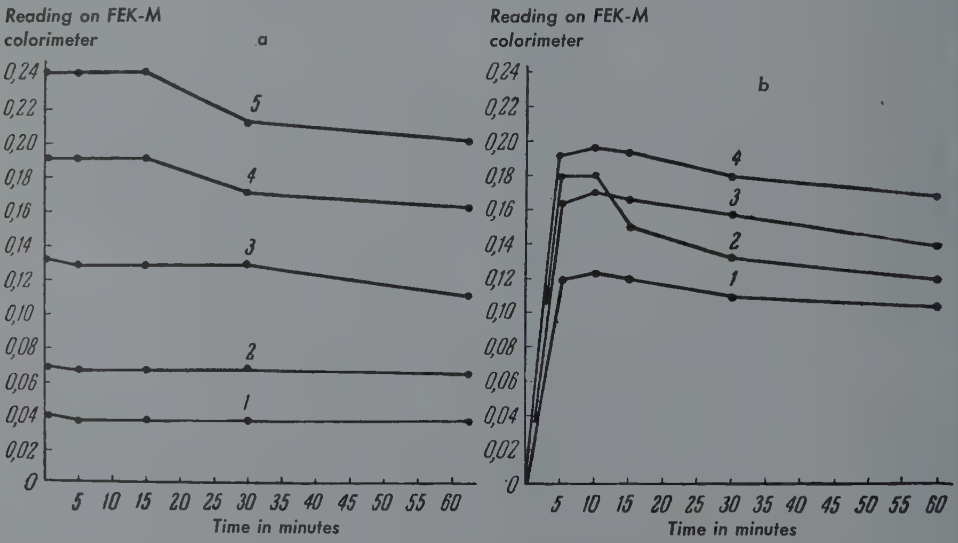

FIG. 3.—Development of phosphomolybdate blue color with time (version of Truog and Meyer). a—In KH_2PO_4 sample solutions (mg. P_2O_5 per 50 ml.): 1—0.005; 2—0.010; 3—0.020; 4—0.030; 5—0.040. b—In acid extracts of peat-podzolic soil (Dolgoruchnaya Agricultural Chemical Experiment Station): 1—0.02 N HCl extract; 2—1% citric acid; 3—0.002 N H_2SO_4; 4—0.5 N CH_3COOH.

system phosphomolybdate complex ⇄ phosphomolybdenum blue.

Conclusions

1. The results of phosphorus determinations in slightly acid extracts of different soils using individual versions of the Deniges' method (Shmuk-Kurilo, Levitskii, Malyugin-Khrenova, Truog-Meyer, Tsintsadze, and Meshcheryakov's second version) show the possibility of using each of these for this purpose. The versions of Truog and Meyer and of Tsintsadze and the second version of Meshcheryakov are especially recommended.

A solution of ammonium molybdate prepared with hydrochloric acid (version of Dickman and Bray) is acceptable for use only for colorimetric determinations of phosphorus in hydrochloric acid solutions. The version of Tsap and the first version of Meshcheryakov are insensitive, awkward, and little suited for large-scale analysis of slightly acid extracts of soils.

2. In the colorimetric determination of phosphorus by the blue color method using acid extracts of soils the preliminary removal of SiO_2 from the solution is not necessary.

3. The colorimetric determination of phosphorus in 0.5 N acetic acid solution may be carried out without previous evaporation or oxidation of the extract if up to 20 ml. of the extract is kept in 50 ml. volumetric flasks.

4. The colorimetric determination of phosphorus in acid extracts of soils by the version of Truog and Meyer may be carried out from 5 minutes to 10 or 15 minutes after adding the reducing agent. In carrying out phosphorus determinations by the second version of Meshcheryakov, it is best to wait for one hour after adding the reducing agent and do the determination during the course of the second hour.

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MINIMUM MOISTURE CAPACITY OF SOILS

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A. A. Izmail'skii (3) in 1893 and P. S. Kossovich (5) in 1904, in studies of the water retaining and conducting properties of the soil, established that with an excess of soil moisture at the surface a certain quantity of moisture is retained in the upper horizons without flowing downwards. This property of soils, which is extremely important for agriculture, was investigated in detail by Kossovich and called by him the minimum moisture capacity (MMC). "The minimum moisture capacity," Kossovich wrote, "is the ability of the soil to retain water at a height not reached by the capillary water which is in immediate contact with the ground water. Its amount does not depend on the height at which the soil layer is located—on the contrary, it is uniform for different heights. It is evident that the moisture of the soil which corresponds to its minimum moisture capacity cannot be transferred within the soil in a state sufficiently liquid to form drops" (5, p. 14). Thus, minimum moisture capacity characterizes the ability of the soil to create a stable supply of moisture when abundant precipitation falls, when snow melts, and when irrigation is applied. With abundant moisture or flooding of the soil surface, the water reaching the soil mass gradually fills all of the pores of the soil and creates an excess of gravitational water. When the water stops coming down from the surface a part of these supplies flow downward and a part is retained by the soil and is practically in a state of immobile suspension. This supply of water in the soil, or, as Kossovich called it, the "minimum moisture capacity," is the basic reserve of water for plant life and consequently one of the most important factors in soil fertility.

A large number of papers have been devoted to the study of this hydrologic constant. Of the papers by Russian authors mention must be made of the investigations by S. I. Tyuremnov (11), N. A. Kachinskii (4), L. P. Rozov (7), S. N. Ryzhov (8), S. I. Dolgov (2), A. A. Rode (6), V. L. Ulasevich (12), N. K. Balyabo (1) and many others. Different investigators have given this constant different names. For example, Tyuremnov called it "absolute moisture capacity," Rozov "maximum field moisture capacity," Kachinskii "water-retaining ability" or "total moisture capacity," while Dolgov and Rode, with full justification, suggest retaining for it the name of minimum moisture capacity.

The method of determining minimum moisture capacity under field conditions has not yet been fixed. Of this L. P. Rozov correctly states: "After the soil has absorbed water from the surface, we should leave it alone for a certain length of time until all the excess water has run down in and an equilibrium in the distribution of the moisture has been established in the soil layer which is of interest to us. . . . Experience shows that the equilibrium distribution of moisture is established in 3 to 4 weeks for the usual clay loam of the subsoil, although its first phase occurs in 4 to 5 days. In practice this moment is detected by making periodic moisture determinations in the soil at all depths" (7, p. 90).

However, in practice, even such an important method as this examination of equilibrium distribution of soil moisture—periodical checking at all depths following absorption of water from the surface—is not observed. As a rule, in the existing instructions on methods for the determination of minimum moisture capacity of the soil, it is recommended that single determinations be made several days after the absorption of water from the soil surface. Several investigators have established different times for taking soil moisture samples, depending on the MMC. For example, Kachinskii, Ryzhov, Balyabo, Dolgov and others recommend determination of soil moisture two or three days after flooding, Ulasevich four or five days, and others recommend other times. In the handbook on soil improvement investigations in the steppe and forest-steppe regions of the European part of the USSR (10), compiled by S. V. Astapov and S. I. Dolgov in 1953 and published by the ministry of Agriculture of the USSR, it is recommended that the determination of MMC of sandy soils be carried out after 24 hours, but for clay loam after 4 to 5 days.

In other words, the time required to establish a moisture equilibrium condition after flooding of the surface soil has not been adequately worked out. This author's experimental data shows that

TABLE 1

The minimum moisture capacity of average eroded and non-eroded ordinary fine clay loam chernozems

Thickness of soil horizon, cm.	Average eroded soil		Non-eroded soil	
	Moisture store in mm. after:			
	7 days	10 days	7 days	10 days
0–20	80.1	67.4	62.3	62.1
20–50	111.0	106.3	85.8	86.9
50–100	160.0	170.7	138.5	131.6
0–100	351.1	344.4	286.6	280.6

this time depends to a considerable degree on the infiltration rate of the individual soil horizons. In an investigation of the moisture physics of properties of eroded ordinary fine clay loam chernozem we obtained the following data on the permeability of different horizons of the soil profile: From the surface (0 to 10 cm.) it is 15.8 centimeters per day (24 hours), while at a depth of 30 to 40 cm. it is 1.44 centimeters per day. On this basis you can judge the MMC of a soil—the time it takes for a soil layer saturated with water to be freed of its excess so there is no transferable moisture. In this case a soil layer 10 cm. thick with a filtration rate of 15.8 centimeters per day is freed of gravitational water within 15 hours, while at a rate of 1.44 centimeters per day it is not freed until after 7 days. If the water in the soil should move through a 100 cm. layer at these rates, it would need 6 days in the first case and 17 days in the second. Consequently, in fine-textured soils with dense illuvial horizons, the moisture equilibrium in the profile would be attained very slowly and the time for determining moisture after flooding would be measured in tens of days. For this reason in our determinations of the MMC of eroded and non-eroded ordinary fine clay loam chernozems of Kuibyshev region, the recommended times for taking moisture samples (2 to 3 days or four to five days) were not sufficient to establish soil moisture equilibrium. We will show some of the results of the investigations.

As seen from Table 1, in non-eroded ordinary fine clay loam chernozems moisture equilibrium occurred only after seven days at 50 cm.; beneath this was gravitational water. Thus in non-eroded ordinary fine clay loam chernozems moisture equilibrium in the top one-meter layer occurs not earlier than 10 days after the end of absorption of water by the surface soil. In average eroded soils in which there is a dense, slightly permeabl horizon below 30 cm., moisture equilibrium in th top one-half meter had not occurred after seve days and the soil moisture continued to drain ou of the upper half-meter layer in notable quantities, as a result of which there was some moisture increase in the second half-meter layer. W find that in average eroded soils the immobile, o equilibrium condition of moisture in the top one-meter layer of soil may occur no earlier than 20 to 25 days. Thus, in fine clay loam soils in the first period after they receive excess moisture relatively stable supplies of water are created but these supplies considerably exceed the amount of water corresponding to the equilibrium MMC.

Clearly, after the soil has received an excess of moisture, we must consider different stages of the retention of suspended moisture. One stage corresponds to the soil-hydrological constant called the minimum moisture capacity, MMC. However, the equilibrium of suspended moisture corresponding to this moisture capacity in fine clay loam and clay soils occurs very slowly, sometimes after two to three months. The MMC represents a certain content of suspended moisture which in a practical sense amounts to an equilibrium. Rode relates it to the category of film-suspended moisture.

Another earlier stage is characterized by the ability of the soil to retain a definite quantity of suspended moisture in the first period following excessive wetting of its surface. In contrast to the equilibrium MMC, this should be called the *proximate* minimum moisture capacity. The proximate MMC is higher than the equilibrium MMC. A portion of the moisture corresponding to the proximate MMC is capable of moving downward. The proximate MMC gradually decreases to an amount corresponding to the equilibrium MMC.

The proximate MMC is explained by low permeability of the soil as a result of its fine texture, solonization, and the presence of compact illuvial horizons. It changes with tillage and increases with the depth of the plow layer. For this reason, calculation of the proximate MMC is of great importance in production.

It is known that in arid steppe regions the basic supplies of water are created by precipitation in the fall and winter and definitely can be judged only by the equilibrium MMC. During the growing period, when rain falls, the proximate MMC is a valuable index, at least to the extent that it characterizes the moisture storage being formed in the soil and being used by the plants immediately following precipitation. In irrigated agriculture the supplies of water in the soil formed by the autumn and winter floodings are determined only by the equilibrium MMC. During the growing period the soil moisture storage formed by floodings are characterized primarily by the proximate MMC. In slightly permeable soils the period between floodings is often shorter than the interval between the end of a flooding and the occurrence of the moisture equilibrium condition in the soil which corresponds to the MMC. In practice the proximate MMC is best determined 48 hours after the end of the surface flooding. From our point of view this period is acceptable for two reasons: First, in easily permeable soils the equilibrium phase of MMC has already begun after 48 hours. Second, in slightly permeable soils it is not possible in practice to take samples for the determination of soil moisture any earlier than 48 hours after the flooding.

As stated previously, the time for determining the equilibrium MMC may be established by the infiltration rate of a given soil. For example, in the soils of Central Asia—formed on loessial easily permeable clay loam deposits—when the absorption of water takes place at a rate higher than 1 meter per day the moisture equilibrium in the top two meters has already arrived by the end of the second day. In fine clay loams in which water is absorbed at rates like 0.01 to 0.1 meter per day the equilibrium cannot occur in less than 10 to 100 days. In this respect Ulásevich's data (12) on the determination of the MMC in dark chestnut and chestnut clay soils (Table 2) is of great interest.

Table 2 shows that in clay soils a ten-day period following the end of flooding of the surface soil is still not long enough for the top one-meter layer to reach its moisture equilibrium. Between the time of the first determination on the third day and that of the second determination on the tenth day, 16.2 mm. of water—or 162 cubic meters per hectare—drained downward from the top one-meter layer. After the second determination another 30.5 mm.—or 305 cubic meters per hectare—drained out of the top one-meter layer. Thus, in this dark chestnut clay soil 467 cubic meters per hectare, amounting to 17% of the MMC, drained from the top one-meter layer.

TABLE 2

The minimum moisture capacity of dark chestnut clay soil (according to Ulasevich's data)

Thickness of soil horizon, cm.	Mosture storage in mm			
	Before	Time after end of water absorption		
		3 days	10 days	60 days
0–20	39.6	74.2	70.1	59.0
20–50	50.3	90.6	76.9	76.6
50–100	89.9	155.7	147.3	138.2
0–100	179.8	320.5	304.3	273.8

TABLE 3

Minimum moisture capacity of a chernozem from the West Caucasus Foreland (according to Tyuremnov's data)

Depth in cm:	0–40	40–60	60–80	80–100	100–120	120–140	140–160	160–180	180–200
Volume wt.	1.14	1.15	1.17	1.20	1.23	1.26	1.35	1.34	1.35
MMC as % of soil wt.	27.0	26.8	25.8	25.2	24.5	23.1	22.5	21.1	21.8
MMC as % of soil volume	30.8	30.8	30.2	30.2	30.1	29.1	30.4	29.6	29.3

In characterizing the soil MMC, it is of great importance to express it not only with respect to the weight, but also with respect to the volume of the soil. Here Tyuremnov's investigations are of great interest. In a study of the MMC of leached fine clay loam (uniform texture) chernozems of the West Caucasus Foreland, he noticed that if the MMC is expressed as a percentage of the volume of the soil, it will even out over the entire soil profile regardless of the density (or volume weight) of the separate genetic horizons. Thus, the product of the volume weight and the MMC expressed per unit weight of the soil should be uniform for all horizons of a given soil which has uniform texture. This property of the MMC expressed per unit volume of soil is clearly illustrated in the following data.

From Table 3 we see that in going downward from the humus soil horizons to the parent material, the volume weight gradually increases from 1.14 to 1.35; the MMC, as a percentage of the soil weight, decreases correspondingly (from 27 to 21%); while the MMC expressed as a percentage of the soil volume is characterized by an approximately uniform figure for the entire soil stratum. Thus the absolute moisture storage cor-

TABLE 4

Minimum moisture capacity (MMC) of the soils in horizons of different densities as percentage of the volume of the soil

Average eroded ordinary fine clay loam chernozem (Firsova, 1954)				Ordinary chernozem (Ulasevich, 1938)				Peat-podzolic forest soil (Vasil'ev, 1950)[a]				Thick, rich virgin chernozem (Bol'shakov, 1950)[a]			
Depth of sample, cm.	Volume weight	MMC		Depth of sample, cm.	Volume weight	MMC		Depth of sample, cm.	Volume weight	MMC		Depth of sample, cm.	Volume weight	MMC	
		As % of soil wt.	In mm.			As % of soil wt.	In mm.			As % of soil wt.	In mm.			As % of soil wt.	In mm.
0–10	1.13	29.9	33.8	0–25	1.01	33.6	33.9	4–9	0.68	50.3	34	0–10	0.97	46.0	44.7
10–20	1.31	25.5	33.4	25–65	1.20	26.9	32.2	9–16	1.06	30.8	33	10–20	1.16	35.5	41.2
20–30	—	23.9	31.3	65–85	1.35	22.7	30.7	16–25	1.34	22.6	30	20–30	1.11	38.6	36
30–40	1.4	21.7	31.4	85–100	1.47	21.4	31.4	25–35	1.44	21.2	30	30–40	1.18	31.4	37
40–50	1.45	21.2	30.7	100–150	1.60	20.7	33.2	35–45	1.54	20.4	31	40–50	1.16	29.5	34
50–60	—	20.5	29.7	—	—	—	—	55–65	1.61	18.8	30	50–60	1.21	29.3	35
60–70	—	21.2	30.7	—	—	—	—	—	—	—	—	140–150	1.37	27.7	32
—	—	—	—	—	—	—	—	—	—	—	—	160–170	1.46	22.3	32
—	—	—	—	—	—	—	—	—	—	—	—	180–190	1.53	22.5	34

[a] Data taken from Rode's monograph (6).

responding to the MMC is the same in equal volumes of soil.

This regular pattern noted by Tyuremnov for chernozems with uniform texture in the profile has been confirmed in other soils. In the literature there is a large amount of data showing uniform equilibrium distribution of soil moisture corresponding to the equilibrium MMC expressed as a percentage of soil volume. We will cite some of the data (Table 4).

Table 4 illustrates the even distribution of the absolute moisture storage in millimeters corresponding to the MMC in profiles of different soil materials independently of the density of the different horizons. It is true that some increase in the MMC of the topmost humus horizons is observed in comparison with those of lower levels. For example, in the upper horizon (0 to 20 cm.) of a rich virgin chernozem the moisture storage corresponding to the MMC is 44 to 41 mm., at 20 to 30 cm. it is 36 mm., and at 180 to 190 cm. it is 34 mm. Obviously, this deviation is explained by the high content of organic residue (roots) in the 0 to 20 cm. layer, and because of its high moisture capacity there is an increase in the total soil moisture storage corresponding to the MMC.

Conclusions

1. When determinations of the minimum moisture capacity (MMC) are made in fine-textured soils, the different stages of suspended moisture must be distinguished. The equilibrium MMC characterizes the amount of suspended moisture which is evenly distributed in the soil profile and is practically incapable of draining downwards. The proximate MMC characterizes the maximal amount of suspended water immediately after the water has entered the soil. A part of the moisture of the proximate MMC is capable of moving downward in the profile and gradually decreases as equilibrium MMC is reached.

2. For the determination of MMC, the time when the equilibrium condition of the soil moisture occurs is fixed by the rate of movement of the water in the given soil profile.

3. Analysis of existing data from the study of the equilibrium MMC of various soils shows that other soil materials having uniform texture comply with the equation of "moisture equilibrium" which Tyuremnov established for chernozems.

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Book Reviews

DIE WICHTIGSTEN BÖDEN DER BUNDESREPUBLICK DEUTSCHLAND

Professor Dr. E. Mückenhausen

The most important soils of the German Federal Republic, (Land und hauswirtschaftlicher Auswertungs- und Informationsdienst e. V.) Wissenschaftliche Schriftenreihe des AID, Heft XIV. Bad Godesberg, 1957.

This work of Professor Mückenhausen is an atlas of 60 profiles in color of the principal soils of the German Federal Republic with a short characterization of their genesis, principal properties, distribution and use. Each of the 60 soil profiles, 25 x 6.5 cm. in size, was drawn in water colors by the artists Krober and Schwartz. The illustration of a profile and its accompanying text occupy two pages (page size is 30 x 21 cm.).

The illustrations of the profiles are preceded by a short general text consisting of a foreword and sections explaining the nature and purpose of publication of the profiles in color and giving necessary information about the development and classification of the soils of Germany as well as general explanations of the 60 profiles shown in the atlas. The last section consists of: descriptions of the methods of selecting the profiles; the technique of preparing water-color profiles; a description of the profiles; characterization of the chemical and textural properties and interpretation of the soils of each profile.

Doubtless the principal value lies in the soil profiles which are, with some exceptions, wonderfully executed, very graphic and true to nature in reproducing the characteristic properties of the soil structure. It must be added that the entire atlas is printed on paper of good quality which has doubtless made possible better reproduction of the color pictures.

The publication of such an atlas must be recognized as an extremely important and valuable beginning which should be broadened and popularized. The reproduction for wide use of well-drawn water-color sketches or of color photographs of the principal types of soils makes possible: first, the establishment of mutual understanding among soil scientists of different countries and clarification of the characteristics and properties of soils according to which they are classified into one type or another; second, the carrying on of more effective discussions regarding the genesis of soils; and third, concrete comparison and discussion of the question of the systematization and classification of soils. All this helps the International Society of Soil Scientists to work out the general principles of a unified systematization and classification of soils.

The publication of such an atlas is not a novelty. An atlas of the forest soils of Japan with descriptive text in English was published earlier. It is a source of regret that, up to now, we do not have a similar atlas, for this is doubtless an important gap which is hindering further spread of the ideas of Dokuchayevian soil science which Soviet soil scientists have developed. The lack of an atlas graphically illustrating the profiles of the principal types of soils of the USSR, we are convinced, frequently leads to inadequate understanding by foreign soil scientists of the types of soils which have been established in the USSR. This applies particularly to soils of the bog types, to sierozems, cinnamon-brown soils, burozems and other types. It must be emphasized especially that no matter how fully or in what detail a soil profile of one type or another is described, in the absence of a reproduction in color of a sketch or photograph of the profile such description is very difficult and is usually interpreted by the reader in terms of his own experience. The greatest difficulty, naturally, occurs in the translation of such descriptions into another language, especially with insufficient knowledge of the Russian language.

An atlas of the profiles of the principal soils of the USSR is necessary, also, because in different countries at the present time there is ever greater delineation of new types of soils, not always on an adequate basis, and the terminology is becoming exceptionally complicated. In this respect the textual part of the atlas being reviewed here can serve as a graphic example. Regardless of the clearly expressed influence of Dokuchayevian soil science in the description of the soil profiles and of their characteristics, there are still a great many ideas which are either not understandable to a Soviet soil scientist or which it is difficult to agree with. Thus, Mückenhausen divides all soils into four large groups:

1. Land soils (Terrestrische Böden)
2. Semiterrestrial soils (Semiterrestrische Böden)
3. Submerged soils (Subhydrische Böden)
4. Peat-bog soils (Moorböden).

If the first group is to be understood as including soils formed without the participation of ground water, it is difficult to understand why they are related to gley soils formed under the influence of flowing water (Stagnogley) and others; or the delineation, under the designation of sierozems, of coarsely humic, thin, weakly developed soils on dolomites. It is hard to consider as independent soil types those which are distinguished under the designations of krasnozem (profile 44), clay pan soils (profile 38 and 42), paleo-soils (profile 37) and others which by their nature reflect the effect of the parent material.

Included in the second group are soils formed under the influence of ground water. Along with young meadow and various gley soils, it includes smonitsa.

The group of submerged soils is not represented in the atlas. The peat-bog soils include peat bogs with various degrees of decomoposition of the peat.

All the soils are characterized with respect to pH (water and salt); total exchangeable Ca and Mg (S); total exchangeable cations Ca, Mg and H (T); the content of H by the difference between T and S; the degree of saturation (V); the CaO content in 1% NH_4Cl, and also K_2O and P_2O_6 by the lactate method; the amount of humus and $CaCO_3$, the C:N ratio and texture. Mention must be made of the small number of analyses, which resulted in occasional failure to differentiate the soils adequately. It would be possible to list more ideas and views which, because their foundations are not convincing enough, stimulate questions and objections. However, that is not the purpose of the review; it is rather to point out how important and useful (regardless of the existing shortcomings or disagreement with the author's interpretations) this work of Professor Mückenhausen is for the understanding of the principal types of soils which are distinguished in the German Federal Republic, and for further consideration of questions of the genesis and classification of soils in general.

Reviewed by S. V. Zonn

ALKALISOILS. THEIR FORMATION, PROPERTIES AND RECLAMATION. NEW YORK. 1951.

(Short Abstract of the Review)

W. P. Kelley

The book by W. P. Kelley, "Alkali soils. Their formation, properties and reclamation," is a monograph of 160 pages with 40 tables and 14 illustrations. Appended is a selected bibliography of 150 references, including papers by K. K. Gedroits, E. N. Ivanova, V. A. Kovda, I. N. Antipov-Karatayev, E. N. Gapon, A. F. Lebedev, E. N. Ratner, I. G. Rozmakhov and S. N. Selyakov.

The monograph is a short presentation of the basic modern concepts of the origin, properties and reclamation of alkali soils. It consists of an introduction and seven chapters.

In the introduction the author dwells briefly on the distribution of alkali soils in the world and on historically important studies of them; he compares the terms used to designate different kinds of alkali soils in different countries of the world (USA, Hungary, USSR, India, South Africa); and he gives the classification of alkali soils used by the U. S. Salinity Laboratory. According to this classification, which is based on the ideas of K. K. Gedroits and A. Zigmond, all alkali soils are divided into: 1) "saline soils," which contain an excess of easily soluble salts but less than 15% exchangeable sodium and have a pH below 8.5; 2) "alkali soils," which contain a small amount of easily soluble salts and more than 15% exchangeable sodium and have a pH higher than 8.5; and 3) "saline-alkali soils," which contain an excess of easily soluble salts and a large amount of exchangeable sodium. Even Kelley himself does not adhere to this classification, considering its basis to be incorrect, and uses the single term "alkali soils" for all such soils regardless of their salt content.

Chapter 1 is devoted to questions of the origin and accumulation of salts. The basic source of salts is considered by the author to be the weathering of rocks; but he attributes great importance to salts given off with volcanic gases and liberated by biological action. Being a partisan of the theory of the continental accumulation of salts, the author considers that the ocean is being enriched with salts at the expense of the weathering of rock of the land. The exceptional variety and unevenness of the salinization of soils and of ground water is explained by the slow rate of horizontal displacement of salt solutions.

Chapter 2 surveys the effect of salts on the chemical, physical and microbiological properties of soils. An especially detailed analysis is given of the effect of salt on the chemical properties of the soil in which most of the attention is devoted to cation exchange reactions, chiefly the interaction between Na^+ and Ca^{++}. The author notes several times that dilution of the soil solution leads to displacement of a part of the exchangeable sodium ions and their replacement by calcium ions from the solution. Another significant factor here is the change in solubility of calcium salts depending on the composition of the salts present in the solution.

In Chapter 3 consideration is given to questions related to the composition of easily soluble salts and exchangeable cations in alkali soils. The author describes the method of determining the composition of salts and exchangeable cations; he divides into groups the alkali soils of the USA; and he characterizes the basic types of alkali soils of the USSR. The author analyzes in detail the effect of the interrelation of water and soil on the results of water extract analyses and of determinations of exchangeable cations; and he notes the doubtful accuracy of determinations of exchangeable Ca^{++} and Mg^{++} in carbonate soils. Grouping of the alkali soils of the USA is done primarily on the basis of their content of exchangeable Na^+—calculation of the $CO_3^=$ ion content and of the $Na^+:Ca^{++}$ ratio in water extracts. The total content of salts is not taken into consideration, so that soils with a salinity of 0.2 to 3% and higher are lumped together in one group.

Chapter 4 is devoted to questions of the formation of sodium carbonate and to the evolution of alkali soils. In it, a detailed survey is made of five kinds of sodium carbonate formation: the formation of sodium carbonate by the weathering of volcanic silicate rocks; the action of neutral sodium salts on $CaCO_3$; the interaction of exchangeable Na^+ with $CaCO_3$ in carbonate soils or the hydrolysis of exchangeable Na^+ in noncarbonate soils (Kelley considers that in soils, sodium carbonate is formed chiefly from the latter reactions); the microbiological reduction of sodium sulfates and nitrates; and the decomposition of plant residues.

The evolution of alkali soils is described in accordance with Zigmond, who noted five stages of development: 1. Salinization—the accumulation of soluble salts in the soils. The composition of salts in soils may be extremely variable; the author considers the causes of the differentiation to be ion exchange and differences in the solubility of salts. 2. Alkalinization—according to Zigmond this indicates adsorption of Na^+ by the solid phase of the soil. Kelley notes that this process always takes place in soils in the presence of sodium salts. But he considers Zigmond's term to be very unfortunate inasmuch as the term limits the concept of "alkali" strictly to adsorbed sodium ions. Kelley emphasizes that the concept of "alkalinization" expresses the essence of the process of "salinization" and it does not make sense to distinguish between these concepts. 3. Desalinization—the leaching of the salts, accompanied by a series of chemical and physical changes in the soils; the author compares this with Gedroits' solonization process. 4. Degradation—replacement of exchangeable sodium ions by hydrogen ions; this corresponds to Gedroits' solodization process. 5. Regradation—according to Zigmond this indicates the repeated accumulation of soluble salts in the soil after degradation.

Kelley notes that all the processes considered follow one another in logical order; however, strict arrangement into such order is not obligatory. Sometimes, with an abrupt change of conditions, the direction of the processes may be reversed. Regradation may take place at any preceding stage of development, as in the case of a sudden rise of the water table.

Chapter 5 surveys questions related to the irrigation of alkali soils. Irrigation does not always cause salinization of the soil; on the contrary it is often a factor in desalinization. But the distribution of alkali soils with irrigation is so wide that it is one of the principal problems of irrigated agriculture. The basic cause of the increase in the salinization of soils with irrigation is the rise in the water table, the capillary rise of the ground water to the soil surface, and the increased dissipation through evapotranspiration. The main cause of the rise of ground water is recognized to be the hydrodynamic pressure developing as a result of the loss of irrigation water by infiltration from the large canals followed on the way to the irrigated fields. In considering the use for irrigation purposes of subsurface water pumped out of vertical wells, the author notes the hydraulic connection between the deep subsurface water and the higher ground water, and emphasizes that mixing of the two does not take place (judging by one of the experiments the composition of the water pumped did not change materially during the 13 years the well was worked).

Chapter 6 is devoted to questions of the effect of alkali soils on plants. It is noted that not all salts have the same action on different plants, and that even the same plant may behave differently toward the same salts depending on the general soil conditions and climatic factors (temperature, light, moisture). The author notes the toxic action of exchangeable sodium ions on plants and recalls cases of plants dying on soils washed by easily soluble salts.

In Chapter 7 consideration is given to methods of reclaiming alkali soils, with emphasis on the need to reckon with actual conditions and the difference in character between soils. Many previous experiments in reclamation have proved to be only temporary: after 10 to 15 years the soil again became alkaline and had to be abandoned. The basic reason for the lack of success in these experiments is considered to be insufficient drainage of the soil: the reclamation was not fully carried out. The author states categorically that "unless a drainage system is installed which is constantly in action and which is suitable for the given conditions, not a single method of reclamation can be successful" (p. 158). The drainage question is analyzed only in the most general terms. Three types of drainage are recalled: tile drainage, open ditches, and pumping. Kelley considers drainage essentially a means for the removal not only of water, but also of salts and it is in just this removal of salts that he sees the basic role of drainage installations.

These are the main ideas of the book. It must be noted that not all of the author's ideas can be accepted without reservations. In our opinion it is not altogether correct to group alkali soils principally according to their content of exchangeable sodium almost without considering their total salt content. The author himself emphasizes that in research on alkali soils, attention must be directed to four of their important properties: 1) composition and total content of easily soluble salts; 2) the ratio of exchangeable cations; 3) pH of the soil; and 4) content of slightly soluble calcium compounds. But in the classification of alkali soils of the USA he neglects to base his considerations on any of these factors and uses as a basis only the content of exchangeable sodium ions and the amount of soluble carbonate ions; there are no data on the content of gypsum, $CaCO_3$ or pH in the tables given in the monograph.

It seems strange that there are almost no theoretical generalizations in the book. In considering the various kinds of salts encountered in the alkali soils of the USA, Kelley notes that they are associated with one locality or another, but he does not draw any conclusions about the pattern controlling the distribution of salts by areas—he just states the facts. Analyzing the question of concentration and composition of ground water, the author cites factual information about the ground water of various regions of California. The different types of ground water differ considerably with respect to the water table, total salt content, and composition of salts, but the author does not classify them even in a very elementary way.

There are no concrete figures in the book on rates of application of irrigation water, threshold content of salts in irrigation water, or the concentrations of salt water recommended for irrigating fine-textured soils.

Some questions are only mentioned, but not analyzed, by the author since in his opinion "they are only of purely theoretical interest". Among such questions are: a) the "negative" adsorption by the soil of chloride and nitrate ions; b) the individual importance of exchangeable calcium and magnesium ions in alkali soils; c) the accuracy of analytical determinations in alkali soils; d) the causes of variation in alkali soils.

But, as a whole, this book is of great interest. The brief, clear presentation of the basic principles of investigation of alkali soils and the usually objective consideration of the work of different investigators make it an exceptionally useful book for soil science and reclamation specialists.

V. P. Kelley's book should be published in Russian translation and provided with a detailed commentary pointing out some of the author's views which diverge from those of Soviet investigators and supplying new information in the field of alkali soils which has appeared since the publication of the American edition.

Reviewed by V. S. Muratova

Chronicles

A STUDY OF SAKHALIN ISLAND SOILS

A. M. Ivlev

INHABITANTS of Sakhalin first engaged in agriculture in the 1860's (1, 15). At the time of Shmidt's (28) visit to Sakhalin agriculture already existed there. From then on agriculture developed unevenly. Sowings sometimes were larger, sometimes smaller.

Until 1926 no investigation of soil cover had taken place. The first conclusion about the character of soils on Sakhalin was drawn by V. V. Dokuchayev on the basis of samples sent to him and analyzed at the University of St. Petersburg. Dokuchayev, as Red'ko (22) wrote, related the soils of the Sakhalin valleys to the type of superficial alluvial soils formed by washing down of fine particles from the adjacent highlands and by flooding from the nearest rivers. This was the so-called river and rain alluvium. According to Dokuchayev's conclusion these processes had stopped. A part of the soils of Sakhalin, as Dokuchayev said, were characterized by a high content of iron oxides, other soils were acid, and in a third kind a mass of undecomposed residue was observed. According to their nutrient content, the soils of Sakhalin were like the soils of the European part of Russia lying to the north of the chernozem zone.

The Sakhalin agronomist Mitsul (15) has given us fragmentary information about Sakhalin soils. He not only described the quality of Sakhalin soils, but referred to their distribution according to elements of the relief. "On slopes which are distinguished by relatively drier locations and by grassy vegetation, there are found fairly deep chernozem clay loam and chernozem sandy loam soils which are capable of giving satisfactory crops over a fairly long period without needing any fertilizers" (15, p. 24). "In the lower reaches of many valleys clay soils are found which are quite suitable for growing vegetables, especially cabbages" (p. 25). "On cliffs and weathered places in the mountains chernozem soil is a fairly common phenomenon although the layer is not of uniform thickness everywhere; the higher up the mountain, the thinner the layer of chernozem becomes. In highland locations the soils encountered are largely stony and clay, but notwithstanding this, with very few exceptions the soils are covered with woody and grassy vegetation" (p. 25). Bog soils which are strongly waterlogged are located in the lowest plots of the valleys.

Comparing the soil characteristics of the central and southern parts of the island, Mitsul notes that the soils of these regions are very similar. He concludes that these parts of the island are quite suitable for the development of agriculture while the northern part "is of almost no agricultural interest, as if nature herself had predestined the region for the hunting of wild animals" (15, pp. 15–16).

Short references to the character of the valley soils of the island are found in Nevel'skii (17) and Busse (8), who wrote that in the river valleys of the shore of Aniva bay "the land is pure chernozem" and that "according to the quality of its soil it is eminently suitable for absorbing an agricultural population."

Interesting information about the character and quality of the soil is found in Avgustinovich (1), who states that in the valley of the Tym river there are "several tens of thousands" of hectares, on which "Sakhalin hemp, as a result of soil favorable to its growth, has stalks which are not exceeded in quality by Russian hemp."

Fragmentary information about the character of the soil and its fertility is also given by A. P. Chekhov[1]. He states that in the Arkhovo river valley "the top 4.5 cm. layer is humus, while the subsoil is pebbles that get so hot on warm days they dry out the roots of the plants, and in the rainy season do not transmit water because they lie on clay."

Fon–Frinken (30) gives a description of the soils of the Lyutoga river valley and notes that on different elements of the relief, soils develop which are variable in texture and which are underlain by variable parent material. Their composition and structure are also not uniform.

Krasnov (13), describing the vegetation, makes some remarks about the characteristic peculiarities of the soil cover. He writes that in the Aleksandrovsk region the soil is slightly weathered and that masses of peat are accumulating on it.

All this information about the soils of Sakhalin is of a purely coincidental nature and is only of historical interest to us.

Among the first investigators we must also include a group of Japanese soil scientists who in 1924–1926 made a search for land on which to sow sugar beets (35) on the southern half of the island (south of 50° N.).

From 1926 to 1928 the soil scientist Michitaro Sugawara (43) compiled a soil map of the southern part of Sakhalin which was finished in 1929 and introduced as a survey soil map at a scale of 1:500,000. In addition, a map of the soil classes was compiled at the same scale; on it the soils were grouped into classes according to texture.

From 1930 to 1945 soil investigations were made on the southern part of Sakhalin by the Japanese soil scientists Sugawara (41, 42, 43), Miyaki and Tamati (36, 37, 38, 39), and Miyamoto (41) who traced the soils on small, local plots of individual farms and compiled a soil map of these areas on a scale of 1:25,000. The soil scientists further described the morphology of individual soil sections in which they determined the agronomic indices and, sometimes, the complete composition. They also studied the liming of acid soils, the application of fertilizers, and methods of soil tillage (31, 32, 33, 34, 35). Miyaki and Tamati (36, 37, 38, 39) compiled a summary of the podzolic soils of the southern part of Sakhalin. Sugawara (12), in the book "Tundra," gave a characterization of peaty soils and compiled the first survey soil map of southern Sakhalin (43).

The Japanese soil scientists included Sakhalin island in the podzolic zone, and distinguished podzols, podzolic soils, degraded podzols and gley-podzolic soils of the alluvial and peaty types.

In the northern part of the island (north of 50° N.) the first soil investigations were carried out in 1926 and 1927 by Krasyuk (12). Krasyuk (12, 3) explored the valley of the Tym, part of the Poronaya valley (down to 50° N. to the former international boundary), and the Arkovo river valley. In a two-year project Krasyuk collected a wide variety of data on the natural history of the central part of the island and a number of soil samples were chemically analyzed.

As a result of this work by Krasyuk, a soil map of the northern half of the island was compiled at a scale of 10 versts to an English inch,[2] an article was written on the soils of Sakhalin (12), and a classification of the soils was compiled.

In his classification, Krasyuk divided all the soils found in his investigation of the area into three geomorphological groups, combining in each of these groups the different soils associated with unique features of the relief. He distinguished three groups of soils on the basis of their soil-forming processes: podzolic, alluvial, and bog soils. These three groups combined thirty-eight types, of which twenty-eight were of the podzolic group. Krasyuk's papers had an important effect on the further investigations of the soil cover of the island. His classifications served for a long time as a basis for the study of these soils, and their division into geomorphological groups. His proposals are still used by the soil scientists of Sakhalin.

After Krasyuk's expedition there was no study of the soil cover of the northern half of the island for more than twenty years. Bits of information about the soils of this part of Sakhalin are found in Ivashkevich (7) and Kabanov (9). They give morphological descriptions of the soils under various plant societies. The papers by Ivashkevich[3] and Kabanov make possible some clarification of the nature of the distribution of the soils under various types of vegetation and consequently provide some ideas of the soil cover. However, the lack of data on the chemical properties keeps us from judging the quality of these soils. Kabanov (9), as well as Krasyuk (12), refers to the development of podzolic, alluvial, and bog soils.

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[1] "Sakhalin Island," Collected Works, Vol. 10, p. 122.

[2] About 1:41,000—Translator.

In the 1930's investigations of the soils of the northern part of the island were undertaken by Kedrov-Zikhman and Nekrasov (11) and by Shcherbilin (29) to determine how promising the development of agriculture there would be.

Tikhomirov and Tanayev, studying the vegetation of the northern part of Sakhalin island, give an incidental description of the soils. All these investigators distinguish podzolic, peat-podzolic, alluvial, and bog soils. Tikhomirov and Tanayev also distinguish a peat soil in various stages of podzolization. After the liberation of the southern part of Sakhalin island from Japanese occupation, more and more attention was devoted to the study of the soil cover of the island and the qualitative characterization of the soils.

In 1946 Petrov (29), visiting Sakhalin in connection with the organization of the Sakhalin Scientific Research Base of the Academy of Sciences of the USSR[4], completed several trips through the southern part. He wrote a short paper on the soils of the southern part of the island and provided a 1:1,000,000 soil map. Petrov distinguishes three groups of soils: podzolic, alluvial, and bog. Among the podzolic soils he distinguishes five types on parent material of different geological ages.

Since 1947 a systematic study has been carried on by the Soil Group of the Sakhalin Scientific Research Base, Academy of Sciences, USSR (later a Branch of the Academy of Sciences of the USSR and at present the Sakhalin Composite Scientific Research Institute, Academy of Sciences, USSR). Workers of this group carried out projects in compiling soil maps and developing large areas of arable soils and studied questions of liming, applying fertilizers, deepening the surface layer, and so on.

From 1949 to 1955 a great deal of work compiling soil maps of the land use area of collective farms of the region was done by the Sakhalin Regional Administration of Land Use and Crop Rotations. In the course of research on these soils, soil scientists of the Administration of Land Use and Crop Rotations collected a wide variety of data on the valley soils. However, because of the absence of analytical data this material (16) has not been processed.

During the same period a study of peat soils of Sakhalin was begun. On the basis of her personal observations and of data from the expedition of the Institute for Peat Reconnaissance of the RSFSR, N. V. Vlastova provided a physico-chemical characterization of the peats and peat soils and worked out measures for their practical use (4).

The soil scientists Ivlev and Tyumeneva (from 1951 to 1955) explored the valley of the Tym river and the train of the Susunai range. In addition, Tyumeneva (in 1954), and later Kozhanova (1955), studied the soils of Sakhalin meadows. At the same time Ivlev (in 1955) made a preliminary survey of the soils of Kholm, Nevel, and Aniva districts and of those of part of Korsakov district.

In 1953 and 1954 O. V. Balutina, Z. V. Iveleva and A. R. Maiorova of the Sakhalin Branch, Academy of Sciences, USSR, under the leadership of Doctor of Agricultural Sciences Chernyi (26), carried out experiments on deepening the surface layer of meadow peat soils, studied the effect of perennial grasses on the formation of soil structure, and the behavior of nitrates in soils during the growing period.

Elykova (1949–1951) and then Storozhenko, Pod'yachev and Kondrasheva (19, 20) studied the liming of peat-gley and meadow-peat soils and the effectiveness on them of mineral fertilizers under a variety of crops.

The foresters of Sakhalin (5, 13, 21, 23) carried out a large amount of work in collection of data and characterization of soils, especially in describing their morphology. Lashikov (14) and Romanov (21), workers of the former Forestry Division of the Sakhalin Branch, Academy of Sciences, USSR, described the morphology of soils under various forest plantings, collected a large number of soil samples, and determined their moisture. Lashkov (14) is one of the first to turn his attention to the development of erosion processes in the mountainous areas of Sakhalin and is essentially the pioneer in this field on the island.

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[3] B. A. Ivashkevich worked on Sakhalin before A. A. Krasyuk and was the first to include Sakhalin soil among the podzolic groups. The first morphological descriptions of the northern part of Sakhalin were given by B. A. Ivashkevich and I. Zuyev (6).

[4] Later a branch of the Academy of Sciences, USSR, and since 1956 the Sakhalin Composite Scientific Research Institute (SKNII), Academy of Sciences, USSR.

In concluding this summary of work relating to the study of soils of the island, mention must be made of the great work done in compiling the soil map of Sakhalin which was carried out by the Fourth Geological Administration of the Ministry of Geology and Preservation of Mineral Resources in 1955.

Soil scientist I. A. Ryashina compiled the 1:1,000,000 soil map of Sakhalin on the basis of soil scientists' work of this Administration's expedition. This is a map of the soil and subsoil. The basic type of soil formation shown is the podzolization.

Since 1951 an expedition from the Institute of Water Economy of the "Rosgiprovodkhoz"[5] has been working on Sakhalin. It has been setting up projects for drainage work. The soil scientists of this expedition, I. M. Kalinkin and R. A. Zenkova, have been studying the soils of land use areas of collective farms in order to carry out soil reclamation measures.

In 1950–51 and in 1956, an extensive study of peats, their deposits, and the calculation of stores of peat on Sakhalin was done by an expedition of the Institute for Peat Reconnaissance. In 1947 N. N. Sushkina (24) collected soil samples and investigated their content of *Azotobacter*. According to her data, *Azotobacter* is completely lacking in the soils of Sakhalin. In 1950–1951 a Novosibirsk expedition, under the leadership of L. G. Retskii, made soil explorations in the land use area of the "Red Tym" state farm in Kirovsk district.

In 1954 scientists changed their minds about soils and the soil-forming process in the southern part of Sakhalin. Bogatyrev and Rudneva (2), workers of the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR, who were on Sakhalin at the time, and the Sakhalin soil scientists A. M. Ivlev, O. P. Spiridonova and A. G. Tyumenova with the participation of the geobotanists A. I. Tolmachev, A. G. Gizh and L. V. Motorina, compiled a preliminary systematic list of soils. The basis of the list was the geomorphologic principles proposed by Krasyuk.

Ivlev (13) compiled a 1:1,000,000 outline soil map of Sakhalin and divided the island into soil regions (8), thereby making Sakhalin an independent soil province with three districts: the northern (podzolic-bog), central (composite peat-podzolic) and southern (peat). The boundaries of these districts coincide with the boundaries of the agricultural soil regions delineated earlier (1954) by the soil scientist Kachiyani (10).

A. V. Mizerov, a worker in the Sakhalin Composite Institute, on the basis of his personal observations, considers that in the southern part of the island the podzolic process is developing and becoming dominant, accompanied by the formation of peat but not of humus. The question of the development on Sakhalin of peat and podzolic soils remains unresolved and requires further investigation.

In 1956 the Sakhalin Composite Scientific Research Institute of the Academy of Sciences, USSR, began the compilation of the Sakhalin sheet of the State Soil Map of the USSR on a scale of 1:1,000,000. This work was done in the summer of 1956 by N. I. Kozhanova and A. V. Mizerov, workers at the Institute.

From 1954 to 1956, foresters of an expedition of the Far Eastern Trust for Aerial Photometry for Forest Management worked out and proposed a classification of the soils according to their degree of erosion. They distinguished three groups of soils: 1) those in which both the litter and the humus horizon are destroyed; 2) those in which the litter is destroyed and the humus horizon partially destroyed; 3) those in which the litter is destroyed but the humus horizon is preserved.

In 1956 E. N. Shchetkina, a soil scientist of the Sakhalin Composite Agricultural Station, began a soil exploration of the lands of the Station's central settlement in the Kirov division (in the Tym river valley) and of the Kholmsk Fruit and Berry Station. Mention must be made of the extensive work in the analysis of soil samples carried out by E. L. Stepanova, Z. V. Ivleva and A. I. Zbruyeva, research workers of the Sakhalin Composite Scientific Research Institute.

As a result of thirty years of study of the soil cover of Sakhalin, a large amount of data has accumulated, but up to the present time the complex and principal question of the genesis and classification of soils has not been answered. There is as yet no single point of view on the soil cover of the island and the character of the soil formation. This applies especially to the southern part of Sakhalin where the soil formation is so unique that it does not correspond to any of the outlines accepted on the continent and requires the setting up of special investigations.

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[5] Respublikanskii gosudarstvennyi institut po proyektirovaniyo vodokhozyaistvennogo i meliorativnogo stroitel'stua, The Republic State Institute for Design and Planning of Water Resources and Reclamation Development.

These investigations will allow us to judge the direction and specific characteristics of the present soil-forming processes on Sakhalin, as a result of which we can work out concrete measures for the use of its soils and the improvement of their fertility.

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ALL-UNION CONFERENCE ON AGRICULTURAL CHEMICAL METHODS OF SOIL INVESTIGATION

E. I. Shkonde

The All-Union Conference on Agricultural Chemical Methods of Soil Investigation took place in Moscow from September 23 to 28, 1957, under the sponsorship of the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR. Taking part in the conference were workers from 152 all-union, zonal and branch institutes, experimental stations, colleges, divisions of the Ministry of Agriculture of the USSR, union republics, territories and regions, and also from a number of agricultural chemical laboratories of the Machine and Tractor Stations. Forty-nine papers were heard and discussed at the conference. They dealt with agricultural chemical methods of soil investigation and with the compilation of large-scale agricultural chemical soil maps.

In the opening address, Academician I. V. Tyurin emphasized the great significance of investigations on methods in agricultural chemistry and in soil science for the solution of practical questions and for the study of the soil cover in the individual soil and climatic regions of the country. The Conference was assigned with the task of discussing creatively the papers presented and of organizing further interdisciplinary work for perfecting present methods and working out new ones for agricultural chemical analyses of soils and for the diagnosis of the nutrition of plants.

In his report, A. V. Sokolov referred to the very great importance of precise agricultural chemical methods for the zonal examination of soils, the correct distribution of crops, and the differential use of fertilizers in crop rotations. He noted that soil maps serve a useful purpose only if they are accompanied by agricultural chemical analyses and by map diagrams showing the effective soil fertility.

G. S. Davtyan reported interesting data on the organization of the agricultural chemical soil service in Armenia, and shared his experience in organizing the agricultural chemical characterization of the soils of the Republic and the rational use of fertilizers.

N. D. Smirnov gave a detailed characterization of the chemical service for agriculture in the postwar period and discussed in detail the status of agricultural chemical laboratories of the Machine and Tractor Stations, their tasks, and the prospects of increased work.

Great interest was aroused by the reports of M. N. Malyshkin and N. K. Krupskii on the principles of large-scale soil examination and the tasks of large-scale soil mapping in relation to an increase in the productive yield of every 100 hectares of arable land. N. K. Krupskii shared his extensive experience in the organization of soil examinations in the Ukraine and in the principles of organization of the agricultural chemical soil service in the system of the Ministry of Agriculture of the Ukrainian SSR and the network of scientific research institutions and colleges. I. G. Andryushchenko reported on the practical use of agricultural chemical indices to set up systems of fertilizing using as an example the state farms of Moldavia. The tasks and principles of compiling agricultural chemical maps were clarified by G. B. Babayan.

It was noted that chemical service for agriculture can be effective only when it has simple, fast and sufficiently precise methods of soil analysis and plant diagnosis. For this purpose it is necessary to set up well equipped agricultural chemical laboratories in immediately available experimental institutions, in the Machine and Tractor Stations and on state farms.

Much attention was devoted at the conference to methods for determining mobile phosphates in the soil. In a survey, D. M. Kheifets referred to the basic requirements for methods of determination of mobile phosphates. He emphasized the necessity for their comparative estimation in different types of soils along with development of indices of phosphate requirements of soils. This work will have to be done by agricultural chemists of the Soil Institute and of other scientific institutions by greenhouse and field experiments.

E. V. Bogdan, K. F. Gladkova, L. I. Dashevskii, N. P. Karpinskii, N. A. Nakaidze, V. A. Frantseson and I. N. Chumachenko reported data on the comparative evaluation of different methods of determining mobile phosphates in individual soils under various agricultural conditions.

N. P. Karpinskii gave a characterization of chemical methods and showed in which order to use phosphate analyses to determine the degree of proper cultivation of soils and their practical use in agricultural production. Another important communication was that of K. F. Gladkova, who used the isotope P^{32} to show the precise amount of secondary fixation of phosphates at the time extracts are made.

A number of reports were devoted to methods of determining potassium in soils. I. G. Vezhenin gave a review of present methods for the determination of mobile potassium and conditions for using them successfully in different soils. D. V. Fedorovskii gave a comparative evaluation of several methods of determining potassium in chernozem soils under different states of cultivation. It appeared that very little attention was devoted to questions of diagnosing the requirements of the soils for potassium fertilizers.

It is especially important to resume work on methods for the determination of soil requirements for nitrogenous fertilizers. The method worked out by I. V. Tyurin and M. M. Kononova for determining hydrolyzable nitrogen needs perfecting. This method should only be used dfferentially.

Two interesting papers by G. I. Chelyadinov and E. M. Lipkind showed the undeniable importance of methods for determining the nitrification capacity of soils. A paper by B. N. Makarov also pointed out the great significance of the study of respiratory processes of the soil as criteria for its fertility.

The conference also heard a report by E. M. Skobets on the importance of the polarographic method in agricultural chemistry and soil science and another by S. I. Dolgov on the importance of moisture and other physical indices in agricultural chemical investigations. A number of papers were devoted to methods for setting up greenhouse and field experiments (B. I. Laktionov, E. M. Movsesyan, K. I. Semergei), and also to frequent questions of soil analysis (K. E. Ginzburg, D. M. Guseinov, L. I. Dashevskii, A. V. Korol'kov, S. F. Negovelov and others).

Special reports were devoted to methods of determining the content of trace elements in the soil (K. V. Verigina, A. I. Gul'akhmedov). The desire was expressed for a considerable broadening of these investigations and for the working out of methods for the determination of mobile forms of these trace elements in different soils. L. I. Korableva reported a method for the determination of mobile magnesium.

Considerable attention was paid at the conference to diagnosing the nutrition of plants according to their external characteristics and the analysis of sap of plants. V. V. Tserling recommended wider use of plant diagnosis methods in combination with necessary soil analyses. In the reports of V. T. Kurkayeva, K. P. Magnitskii, M. F. Mosyuk, O. G. Oniani and E. I. Tukalova, experimental data were shown concerning the successful use of plant diagnosis methods on different soils and under different plants (tea, vegetable and grain crops). The successful introduction of the method of plant diagnosis has been facilitated by the recent appearance of field laboratories under Davtyan, Tserling, Magnitskii, Golubev and others.

A review of modern methods of determining the soil requirements for limestone was given by D. L. Askinazi. He also gave the basis for the quantity of limestone to use, depending on the properties of the soil, the kind of limestone materials, and other fertilizers being applied. He showed that for broad, large-scale analyses the present method, which determines the limestone requirements of soils by the pH of the salt extract in relation to the soil texture, is fully acceptable.

M. Katsas and G. Rozovkis reported data on the mathematical relations of certain indicators of the limestone requirements of Lithuanian soils. The amounts of limestone to be applied to different types of soils were determined by correlating the data from field and laboratory investigations. A. Zemite presented a method of determining the amount of limestone to apply according to the soil content of active cations in relation to soil texture and amount of humus.

In his presentation, O. K. Kedrov-Zikhman reported the results of work done in his laboratory on the quantity of limestone to be applied in connection with different forms of limestone fertilizers and nutrient conditions in the soil. Yu. F. Pil gave experimental data on the effectiveness of limestone and gypsum on solonized soils.

K. V. Verigina gave a review and evaluation of present methods for determining adsorbed calcium and magnesium in carbonate soils.

The great importance of measures for providing and accumulating organic fertilizers and peat is well known. In the papers of M. D. Bakhulin and of Fatchikhina, information was given on methods of evaluating different peats as fertilizers.

Those attending the conference unanimously favored the presentation of the country's senior agronomist, P. E. Gruzinov, who suggested a number of measures for organizing the production of agricultural apparatus and for improving the work of supplying them to the agricultural chemistry laboratories of the Machine and Tractor Stations and experimental institutions.

For those participating in the conference there was a demonstration of apparatus and instruction in soil analysis using the flame photomete (D. N. Ivanov), in accelerated mass analysis o soils (I. F. Golubev), in rapid analysis for plan diagnosis (V. V. Tserling), in determination o humus and nitrogen in soil (N. P. Bel'chikova), in determination of the content of trace element in the soil (K. V. Verigina), in methods of working with radioactive isotopes (I. P. Serdobo skii), and in work with a portable colorimete (S. A. Lanskii).

The conference passed a resolution emphasizing the need for working out a number of questions on methods, on refining apparatus, and s on.

ACTIVITIES OF THE VORONEZH DIVISION OF THE ALL-UNION SOCIETY OF SOIL SCIENTISTS

P. Aderikhin

THE activities of the Voronezh Division of the All-Union Society of Soil Scientists for 1956 and 1957 were directed at intensifying organizational work, developing scientific investigations, and spreading knowledge about the soil among the population of Voronezh region.

Successful fulfillment of a task assigned to the office of the Division can be reported: the enrollment of all soil scientists and agricultural chemists of Voronezh region as members of the Society of Soil Scientists. Also, a beginning has been made on the work of uniting in our Division the soil scientists of neighboring regions (Tambov, Lipetsk, Belgorod, Orlov, and Kursk). A considerable part of the soil scientists' collectives of the Tambov, Belgorod and Orlov region agricultural administrations have been accepted as members of the Voronezh Division.

During the winter periods of the last two years, periodic meetings have been called of the soil scientists of the Division. Among the questions discussed at the meetings have been the results of field work of expeditions, and investigations by departments of soil science of the University and of the institutes of agriculture and forestry. At scientific seminars there were discussions of the nomenclature and classification of soils of Voronezh region, the application of fertilizers, and so on. In summer the soil scientists went out on expeditions into the various districts of Voronezh and neighboring regions. During these expeditions, the soil scientists carried on extensive work in disseminating knowledge of the soil to the population. At field camps, at gathering places, and in clubs of collective farms there were conversations, lectures, and reports given. The basic themes of the conversations and lectures were: what soil is, and how it is formed; the properties of soils and their differences in nature; the geographic distribution of soils in nature; the fertility of soils and how it is affected; soil as the basic medium for agricultural production; soil structure, its formation and importance in agriculture; soil texture and its agricultural importance; the importance of soil nitrogen in the lives of plants; what soil erosion is, what damage it causes, and how it can be controlled.

To interest the public in soil science, P. Aderikhin has written a popular science book on "The Soils of Voronezh Region, Their Properties and Fertility." The authors' collective, consisting of 10 members of the Society, is now at work on the compilation of a monograph, "The Soils of Voronezh Region." As requested by the Zonal Commission, Society members P. G. Aderikhin, E. P. Tikhova, I. A. Santalov and N. A. Kovbasenko, with the cooperation of collectives of soil scientists from a number of institutions of the region, have carried out a division into soil regions of the six regions of the central chernozem belt on the basis of which a map of the soil regions and a description of the soils and their agronomic characteristics have been compiled. Similar work was carried out separately for Voronezh region.

During 1957 members of the Society took part in numerous region production conferences and also in scientific conferences at the Ministry of Higher Education (on soil regionalization and on trace elements), and at the Ministry of Agriculture (on questions of soil fertility).

Collectives and individual members of our Society took part in popular science presentations at colleges, institutes and regional organizations.

The University soil scientists P. G. Aderikhin and E. P. Tikhonova, at the invitation of the Soil Institute, Academy of Sciences, USSR, presented papers on the agricultural chemical characterization of the basic types of soils of the central chernozem belt.

A collective of the Department of Soil Science of the Agricultural Institute (M. S. Tsyganov, S. N. Ovchinnikov, K. V. Tyurin and others) is working on questions of genesis, geography, and erosion of soils of Voronezh region.

A collective of the Department of Soil Science of the Forestry Institute (A. A. Pchelin, I. P. Chigirintsev and others) has carried out a study of the anti-erosion properties of chernozem soils and the genesis, geography, and forestry capabilities of sandy soils of the region.

Many collectives of the Voronezh Region Agricultural Administration, with the participation of students of the soil divisions of the University, have studied the soil cover of collective farms of the Buturlinovskii, Vorontsovskii, Vorob'evskii and other districts of Voronezh region for the compilation of 1:10,000 and 1:25,000 soil maps.

Soil scientists of the "Agrolesoproyekt"[1] are carrying out investigations of the soils in Eastern Siberia this year.

During the current year the collective of Voronezh soil scientists has published more than 30 scientific articles in the national and local press.

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[1] Planning and Research Association of the Main Forestry Administration of the Ministry of Agriculture, USSR.

THE WORK OF THE BASHKIR DIVISION OF THE ALL-UNION SOCIETY OF SOIL SCIENTISTS

S. N. Taichinov and M. S. Shigayev

THE Bashkir Division of the All-Union Society of Soil Scientists was founded in February, 1957, and at the present time has thirty-seven members who are working in various scientific or producing institutions of the republic. Since the time of its founding the Division has held two general meetings of members of the Society and three sessions of the presidium at which the subjects discussed were the project for writing the rules and regulations, plan of work, and other organizational questions. The following reports and communications were heard at the general meetings: 1) Prof. S. N. Taichinov, "The results of the All-Union Conference at the VASKHNIL[1] on the new system of soil management suggested by T. S. Mal'tsev"; 2) Prof. G. V. Vakhrushev, "The neotectonic geology of the Bashkir area of the Ural Foreland"; 3) Soil scientist U. I. Bayazitova, "The use of bauxite deposits in increasing the fertility of soils"; 4) N. L. Kareyev, "A system of soil management on the carbonate chernozems of Bashkiria"; and 5) Petrovka (assistant in the Department of Agriculture and Soil Science in the Chelyabinsk Institute for the Mechanization and Electrification of Agriculture), "The results of a study of the new method of soil management according to T. S. Mal' tsev."

The presidium of the Bashkir Division of the Society considered subjects for plans for scientific research work in soil science by the Bashkir Scientific Research Institute for Agriculture and the Institute of Biology of the Bashkir Branch of Academy of Sciences, USSR. This Division of the Society took an active part in working out the zonal measures for assuring the output of agricultural products from a 100 hectare area of arable land (a division according to the natural conditions of Bashkiria, its system of agriculture and soil management).

Members of the Society are taking part in publishing work and in popularizing the achievements of agricultural soil science. The monograph by S. N. Taichinov, "Agricultural soil regions and increasing productivity" has been sent to the printer. M. M. Turovtsev and M. M. Merinov have published a brochure, "Floodplain soils of the Bashkir ASSR" under the editorial direction of V. I. Shrag. M. S. Shigayev has published the sketch, "Fallow in the crop rotations of Bashkiria" with a brief characterization of the soils of the moist zone (Symposium published by Sel'khozgiz, 1957). E. M. Rakhimov published the sketch "Changing spring wheat into winter wheat" in the symposium "Along the Michurinian path."

In the last period members of the Society have published articles in national journals and in regional newspapers.

Under the heading of help supplied to producers, members of the Society went out into the districts, held scientific engineering conferences and consulted with local agronomic personnel. Twenty-seven lectures were given on current agricultural topics and help was provided in questions on methods and organization of soil fertility, crop rotations, and so on. The lectures were attended by more than 2000 people.

The presidium of this Division of the Society organized the press coverage by a group of scientists of the organization of a Soil Division in the School of Biology of the newly re-established Bashkir State University. The Society also stimulated a petition to the Council of Ministers of the Bashkir ASSR requesting the re-establishment of the South Ural National Forest.

Scientific workers in the field of soil science at the Institute of Biology, Bashkir Branch, Academy of Sciences, USSR, under the direction of G. A. Sklyarov, M. S. in Agriculture, have been studying the genesis of gray forest soils and their physical properties in the forested highland regions of the Republic. Interesting data have been obtained on its soil variation in connection with the relief, its parent material, and the nature of its vegetation. The senior scientific worker at the Institute of Biology, M. N. Burangulova, under the direction of Prof. V. G. Kanarev is working out methods of fractionating the organophosphorus compounds of the soils. Data have been obtained on the composition of organophosphorus compounds of the gray forest soils of Bashkiria.

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[1] The V. I. Lenin All-Union Academy of Agricultural Sciences.

A small group of soil scientists in the reorganized Scientific Research Institute for Agriculture has been doing a study on the hydrophysical properties of soils (Merinov) and compiling a map showing the distribution of erosion with measures for its control which have been worked out (Turovtsev). The completed part of the data was used as the basis for the zonal measures worked out by a commission for increasing the fertility of the soils and the productivity of agricultural crops in the Republic.

A 20-man soil group of the Division of Land Management and Crop Rotation, Ministry of Agriculture, Bashkir ASSR, headed by detachment chiefs S. Kotel'nikov and V. Arkhangel'skaya carried out extensive work on the development and investigation of new lands in the four administrative districts of the Bashkir Ural Hinterland (Abzelilovsk, Baimaksk, Zilairsk and Khaibullinsk).

At the present time steps are being taken to establish what might prove to be extensive connections with production workers and to attract them to the general work of the Society.

AWARD OF THE V. V. DOKUCHAYEV GOLD MEDAL AND THE V. R. VIL'YAMS PRIZES

On December 27, 1957, the Presidium of the Academy of Sciences awarded the V. V. Dokuchayev Gold Medal to Doctor of Agricultural Sciences Aleksei Andreyevich Rode for his book, "Soil Moisture."

On May 27, 1957, the Scientific Council of the Timiryazev Academy of Agriculture awarded the V. R. Vil'yams prizes for 1956 as follows:

First Degree. To Doctor of Agricultural Sciences Professor Konstantin Pavlovich Gorshenin for his book, "Soils of the Southern Part of Siberia from the Urals to Baikal."

Second Degree: To an authors' collective under the editorial direction of Professor S. P. Smelov for the book "Meadow Culture on River Floodplains."

Third Degree: To Doctor of Agricultural Sciences Professor Ivan Fedoseyevich Garkusha for his book, "The Cultivation of Soils as the Modern Stage of Soil Formation."

ALEKSEI NIKOLAYEVICH KOSTYAKOV

A Group of Colleagues and Pupils

Soviet reclamation science has suffered a severe loss. On August 30, 1957, an outstanding scientist in the field of water management, Corresponding Member of the Academy of Sciences of the USSR, Active Member of the V. I. Lenin Academy of Agricultural Sciences, Honored Scientist and Engineer of the Russian Socialist Federated Soviet Republic, Director of the Department of Agricultural Reclamation of the Moscow Institute of Engineers of Water Resources, Professor Aleksei Nikolayevich Kostyakov, died at the age of seventy-one following a protracted and severe illness.

The productive and scientific activity of Professor Kostyakov began almost half a century ago. After graduating in 1912 from Moscow Agricultural Institute (now the K. A. Timiryazev Agricultural Academy) with the specialty of agricultural hydrological engineering, he was retained for scientific work (with Professors V. R. Vil'yams and V. V. Podarev). During the period from 1912 to 1917 Kostyakov set up the first modular experimental reclamation investigations in Russia in the Division of Land Improvement. On the basis of these there developed a network of scientific institutes and experimental stations in all the main regions of the Union after the Russian revolution.

Kostyakov not only collected but also drew general conclusions from the experimental data of reclamation both at home and abroad, and he made available for productive purposes scientifically based methods of planning and exploiting reclamation systems; he was the first to work out the program and methods for reclamation investigations. The results of this work, which was first carried out in our country, were presented as early as 1919 in several volumes, "Transactions of the Hydromodel Section" and "Data for Experimental Reclamation" (which appeared under Kostyakov's editorial direction), and also in two of his monographs, "A Survey of Irrigation Rates in Different Countries" and "The Arrangement and Results of Investigations in the Field of Irrigation in North America."

For general application of experimental reclamation work at different sites to science and methods and for working out scientific questions, Kostyakov organized a special experimental reclamation laboratory which, in 1923, became the State Institute for Agricultural Reclamation and was subsequently reorganized into the All-Union Scientific Research Institute for Hydrological Engineering and Reclamation. It may be said without exaggeration that for forty years the director of scientific investigations in agricultural reclamation was A. N. Kostyakov.

In 1933 Kostyakov was selected as a Corresponding Member of the Academy of Sciences of the USSR, and from 1939 to the last days of his life he directed work on the problem of the administration of water management, investigating the relativity of surface and subsurface water and working out methods to utilize them in meeting the needs of the national economy. On this problem he and his colleagues and scientists in the Section of Water-Resource Problems, Academy of Sciences, USSR, published a series of important papers, one of which, "The Effect of Irrigation Systems on Ground Water Conditions, 1955", was honored with the prize of the Presidium, Academy of Sciences, USSR.

In addition to his leadership and to his execution of extensive scientific research work, Kostyakov wrote a number of scientific papers which placed him in the first rank in the agricultural reclamation field. Among his most important works are: "The Basic Elements of Calculating Drainage Systems" (1916), honored with the prize of the Russian Academy of Sciences in 1917; "The Basic Elements of the Calculation of Irrigation Systems and the Study of Them" (1919); "On the Model of Flow" (1931); "Mechanical Drainage of the Soil" (1929 and 1935); "Determining the Distance Between Drains" (a report to the International Congress of Soil Scientists, 1930); "Methods of Designing Irrigation Systems in Cotton Regions" (1932); and "New Methods of Irrigation in Modern Irrigation Construction" (1933). Kostyakov's greatest work was "The Foundations of Reclamation," which went through five editions. The last of them was awarded the Stalin Prize, First Class, in the category "Science." Kostyakov's works have been published in China, Bulgaria and other countries.

Kostyakov's enormous erudition, knowledge and talent for organization allowed him not only to work out theoretical questions, but also to write such works as "The Prospects of Reclamation in the USSR" and "Reclamation and the Harvest," both of which contain concrete proposals for the development of irrigation in the arid regions of the country for the radical control of drought, especially in the Volga Hinterland.

Kostyakov was chairman of the government commission on acceptance for the greatest national irrigation structures, the great Fergana canal and the Katta-Kurgansk reservoir.

Being an outstanding scientist and an excellent organizer of the reclamation work of our country, from 1919 until the end of his life he took part in the work of the Five-Year Plans of the USSR and of the Ministry of Agriculture and headed the Departments of Agricultural Reclamation which he had begun in the Timiryazev Agricultural Academy and in the Moscow Institute of Engineers of Water Resources.

Kostyakov's teaching activities were extremely varied and fruitful. Many of his pupils became professors, instructors and scientific workers. In recent years many of his pupils went to China and to the countries of the people's democracies.

He skilfully combined his great scientific, productive and teaching activity with active social work, being a Deputy in the Regional Soviet from 1934 to 1939 and in the Moscow Soviet from 1939 to 1949.

The Soviet government valued Kostyakov's services highly and rewarded him twice with the Order of Lenin, three times with the Order of the Red Banner of Labor and with medals.

Kostyakov was not only a talented scientist and an outstanding teacher and creator of the science of reclamation, but he also had superb human qualities: exceptional modesty, responsiveness, and an attentive relation with people. Until the last days of his life he stood at the head of reclamation in our country and remained a true son of the fatherland. The bright memory of Aleksei Nikolayevich Kostyakov as the founder of the science of reclamation, an outstanding investigator, and wonderful human spirit will always be preserved in the hearts of reclamationists, hydrological engineers, soil scientists, hydrologists and all his pupils, while his enormous scientific heritage will promote the progress of the science of reclamation in the Soviet Union in the future.

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